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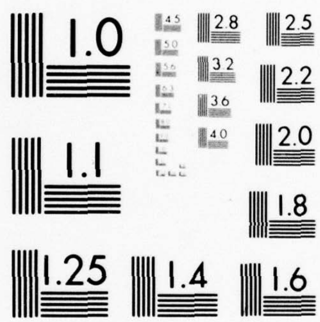

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LIFE CYCLE COST ANALYSIS GUIDE

NOVEMBER 1975

JOINT AFSC/AFLC COMMANDERS'
WORKING GROUP ON LIFE CYCLE COST
ASD/ACL
WPAFB, OHIO 45433

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Preface

Air Force Regulation 800-11 states that the Air Force will, to the maximum practical extent, determine and consider life cycle cost in various decisions associated with the development, acquisition and modification of defense systems and subsystems and in the procurement of components and parts. The purpose of this guide is to provide information and procedural guidance on the use of life cycle cost analysis. This guide should help program managers determine, describe and manage life cycle cost analyses needed for program decisions. It should also help cost, operations research and other analysts organize and initiate life cycle cost analysis efforts.

This document provides guidance on the use of life cycle cost analysis covering a broad spectrum of acquisition program issues. Changes have been made in this publication to reflect comments and suggestions on the June 1975 edition. This document is intended to be used in conjunction with existing policies. If it is found inconsistent with official guidance, regulations, or directives, the provisions of the official directives apply.

Comments on and suggestions for improving this document are solicited and should be submitted to ASD/ACL, WPAFB, Ohio 45433.

This guide has been reviewed and approved.

John D S Gibson

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Table of Contents

	Page
PREFACE	
CHAPTER 1 - GENERAL	1-1
1-1 Background	1-1
1-2 Life Cycle Cost Reduction Opportunities	1-2
1-2.1 Research and Development Actions	1-2
1-2.2 Acquisition Policies	1-3
1-2.3 Design Actions	1-4
1-3 Life Cycle Cost Analysis	1-4
1-3.1 Definition of Life Cycle Costing	1-4
1-3.2 Role of LCC Analysis with Respect to Design	1-4
1-3.3 Scope and Spectrum of LCC Analysis Activities	1-5
1-4 Approach and Scope of Guide	1-6
CHAPTER 2 - SYSTEM ACQUISITION OVERVIEW	2-1
2-1 Objective	2-1
2-2 Scope	2-1
2-3 System Acquisition Summary	2-1
2-4 Conceptual Phase	2-2
2-5 Validation Phase	2-3
2-6 Full Scale Development Phase	2-5
2-7 Production Phase	2-6
2-8 Deployment Phase	2-7

		Page
CHAPTER 3 -	ACQUISITION PROGRAM EVENTS AND ACTIVITIES RELATED TO LIFE CYCLE COST ANALYSIS	3-1
3-1	Objective	3-1
3-2	Conceptual Phase Program Events and Activities Related to Life Cycle Cost Analysis	3-1
	3-2.1 Draft Required Operational Capability (ROC)	3-1
	3-2.2 Final ROC	3-1
	3-2.3 Advocacy Package	3-2
	3-2.4 Decision Coordinating Paper (DCP)	3-2
	3-2.5 Independent Cost Analysis (ICA)	3-2
3-3	Validation Phase Program Events and Life Cycle Cost Analysis Related Activities	3-2
	3-3.1 Program Management Plan (PMP)	3-2
	3-3.2 System Specification	3-3
	3-3.3 Statement of Work (SOW)	3-3
	3-3.4 Contract Data Requirements List (CDRL)	3-3
	3-3.5 Request for Proposal (RFP)	3-3
	3-3.6 Source Selection Decision	3-4
	3-3.7 Decision Coordinating Paper (DCP)	3-4
	3-3.8 Independent Cost Analysis (ICA)	3-4
3-4	Full Scale Development Phase Program Events and Life Cycle Cost Analysis Related Activities	3-4
	3-4.1 Program Management Direction (PMD)	3-4
	3-4.2 Program Management Plan (PMP) Update	3-5
	3-4.3 Preliminary Design Review (PDR)	3-5
	3-4.4 Other Design Reviews	3-5
	3-4.5 Subsystem Testing	3-5
	3-4.6 Critical Design Review (CDR)	3-5
	3-4.7 System Testing	3-5
	3-4.8 Establishment of Baseline Configuration	3-6
	3-4.9 Production Request for Proposal (RFP)	3-6
	3-4.10 Decision Coordinating Paper (DCP)	3-6
	3-4.11 Independent Cost Analysis (ICA)	3-6
3-5	Production Phase Program Events and Life Cycle Cost Analysis Related Activities	3-6
	3-5.1 Program Management Direction (PMD)	3-6
	3-5.2 Program Management Plan (PMP) Update	3-6
	3-5.3 Verification Reviews	3-7
	3-5.4 Engineering Change Proposals (ECPs)	3-7
	3-5.5 Life Cycle Cost Verification Testing	3-7

		Page
3-6	DSARC Determinations and Their Relationships to Program Events and Specific Life Cycle Cost Analysis Tasks	3-7
	3-6.1 Introduction	3-7
	3-6.2 General	3-7
	3-6.3 The DSARC I Review (Program Initiation)	3-8
	3-6.4 The DSARC II Review (Full Scale Development)	3-10
	3-6.5 The DSARC III Review (Production)	3-11
CHAPTER 4 -	SPECIFIC LIFE CYCLE COST ANALYSIS TASK DESCRIPTIONS	4-1
4-1	Objective	4-1
4-2	Conceptual Phase Analysis Tasks	4-1
	4-2.1 Life Cycle Cost Implications of Requirements	4-1
	4-2.2 Determining the Best Employment Concept, Support Concept and System Concepts and Performance Characteristics	4-3
	4-2.3 Cost of Ownership Assessment	4-6
	4-2.4 Preparation of Independent Cost Analysis (ICA) for DSARC I	4-7
	4-2.5 Development of a Procurement Approach	4-9
	4-2.6 Planning the Use of Life Cycle Cost in the Validation Phase Source Selection	4-11
4-3	Validation Phase Analysis Tasks	4-12
	4-3.1 Validation Phase Life Cycle Cost Design Trade Studies	4-12
	4-3.2 Cost of Ownership Refinement	4-14
	4-3.3 Preparation of an Independent Cost Analysis (ICA) for DSARC II	4-16
	4-3.4 Refinement of the Procurement Approach	4-18
	4-3.5 Life Cycle Cost Verification Test Plan	4-21
	4-3.6 Planning for and Using Life Cycle Cost in the Full Scale Development (FSD) Source Selection	4-22
4-4	Full Scale Development Analysis Tasks	4-23
	4-4.1 Detailed System and Support Life Cycle Cost Design Trade Studies	4-23
	4-4.2 Cost of Ownership Refinement	4-25

		Page
4-4.3	Preparation of Independent Cost Analysis for DSARC III	4-27
4-4.4	Planning the Use of Life Cycle Cost in the Production Contract Source Selection and Negotiations	4-29
4-5	Production Phase Analysis Tasks	4-31
4-5.1	Engineering Change Proposal (ECP) Reviews	4-31
4-5.2	Development of Warranty/Guarantee Option Selection Decision Guidance	4-32
4-5.3	Life Cycle Cost Verification Testing	4-33
CHAPTER 5 -	METHODS AND TERMS USED IN LIFE CYCLE COST ANALYSIS	5-1
5-1	Objective	5-1
5-2	Developing New LCC Analysis Approaches	5-1
5-3	Life Cycle Cost Analysis Methods and Terms	5-1
5-3.1	Introduction	5-1
5-3.2	Cost Estimate Preparation Related Methods	5-3
5-3.3	Engineering and Other Analysis Methods	5-14
5-3.4	Analysis Methods for Management Decisions	5-19
5-3.5	Important Life Cycle Cost Analysis Related Terms	5-25
5-3.6	Contract Incentives	5-27
APPENDICES		
A	Life Cycle Cost Plan Preparation Guidance	A-1
B	Planning, Programming, and Budgeting System Overview	B-1
C	Descriptions of Representative Life Cycle Cost Models	C-1
D	Bibliography	D-1
E	Abbreviations and Acronyms	E-1

		Page

FIGURES

5-1	Life Cycle Cost Analysis Approach	5-2
5-2	Program/Work Breakdown Structure Relationships	5-4
5-3	Cost Breakdown Example	5-5
5-4	Logistics Performance Factors--Acquisition Through Life Cycle	5-16
5-5	Probability of Incurring Estimated System Cost, Theoretical	5-21
5-6	Probability of Incurring Estimated System Cost, Past Experience	5-22
5-7	Present Value Computation Format	5-25
B-1	Planning, Programming, and Budgeting System (PPBS)	B-2

TABLES

3-1	DSARC I Determination/Conceptual Phase Program Event/ Specific Life Cycle Cost Analysis Task Relationships	3-9
3-2	DSARC II Determination/Validation Phase Program Event/ Specific Life Cycle Cost Analysis Task Relationships	3-11
3-3	DSARC III Determination/Full Scale Development Program Event/Specific Life Cycle Cost Analysis Task Relationships	3-12
5-1	Discount Factors	5-24

Chapter 1

General

1-1 Background

The high cost of defense systems and the rapidly increasing cost of supporting them after they are placed into operation, is a considerable concern to the Department of Defense. The cost of operating and supporting systems over their useful life is generally greater than, and often several times greater than the initial acquisition cost. Therefore, including these future costs as part of the decision criteria just makes good sense. Reduction in operating and support (O&S) costs can be brought about primarily through increased consideration of these costs in various design and support decisions. Since the objective is to reduce life cycle cost, i.e., total cost, equal emphasis must be given to all costs, research and development, production, and operating and support.

Current DOD management emphasis on cost is directed at all three areas. This cost consciousness is expressed in management principles, management concepts and management review procedures. Terms such as affordable cost, design to cost (DTC), and life cycle cost (LCC) are receiving top DOD management emphasis. Program managers are now expected to have visibility of the following:

a. The total ownership cost of the proposed weapon system.

b. The major operating and support cost elements.

c. The principle design and performance parameters which drive major cost elements.

d. The logistics support alternatives and their cost impact.

e. The areas of greatest uncertainty in estimating costs.

The program managers should be prepared not only to present the preferred design and logistics support concept, but the alternatives that were studied, the reasons why they were rejected, and how the alternatives impacted on the life cycle cost of the weapon system.

The necessity to initiate these analyses as early as possible in a program cannot be over emphasized. For some programs this will be during concept development; in any case it should be prior to DSARC II. As an acquisition proceeds from program initiation through full-scale development, to production and deployment, the design details and, consequently, the operating and support requirements become progressively

better defined. Concurrently, however, the ability to make design changes to reduce operating and support requirements becomes more limited. Thus, the decisions having the greatest impact on the life cycle costs must be made at an early stage in the acquisition process when the least amount of information is available about the proposed weapon system and how it will be operated.

This means that life cycle cost considerations must become an important part of early program deliberations. Although early estimates of operating and support costs will not be accurate, they can be used to assure that early program decisions are consistent with program design to cost and life cycle cost objectives. Secretary of the Air Force Program Reviews (SPRs), Program Assessment Reviews (PARs) and Command Assessment Reviews (CARs) now call for the periodic reporting of the results of trade-off analyses which have been performed and which are planned, including design to cost and life cycle cost considerations and activities.

1-2 Life Cycle Cost Reduction Opportunities

There are a wide range of activities open to the Air Force to reduce costs. Their full implementation will require the timely and sound consideration of costs by people throughout the Air Force. In many situations this will involve the application of life cycle cost analysis. The total spectrum of these cost reduction opportunities falls into three general categories which follow:

1-2.1 Research and Development Actions

a. Development of a technology base with explicit consciousness given to return on investment.

b. Conscious and determined use of technology to reduce cost.

c. Creation of viable options which will allow timely lower risk development of new systems by:

(1) Developing and considering alternate paths to the same goal.

(2) Developing and testing "brass board" or experimental configurations, prototypes, advanced development models and advanced components in response to anticipated need.

d. Using competition wherever possible between technical approaches and developers.

e. Selecting programs among competing solutions such that:

(1) Technical feasibility is a necessary but only one of several criterion for proceeding with a program.

(2) Program progress is geared to demonstrated performance milestones rather than arbitrary schedules or contract constraints using a strong test and evaluation program, at the component as well as systems level.

(3) Greater emphasis is placed on product improvement as a potentially effective alternative to a new development.

f. A strongly supported Independent Research and Development (IR&D) program with the results and benefits made clearly visible.

1-2.2 Acquisition Policies

a. Use of end-item minimum performance goals or specifications, selected to allow maximum trade-off flexibility, rather than detailed design specifications for systems, subsystems and components.

b. Clear identification of both mandatory and desirable system performance characteristics.

c. Periodic and timely feedback of estimated production and operating and support costs to permit early corrective actions in high risk and design problem areas.

d. Timely introduction of all requirements and design considerations in order to avoid later costly engineering changes.

e. Appropriate use of standardization.

f. Consideration of personnel and training cost factors early in the acquisition process in order to influence design trade-offs.

g. Use of producibility and value engineering techniques in high cost areas early during development.

h. Use of contract specifications, terms and conditions which will encourage maximum permissible trade-off flexibility among cost, performance and schedule.

i. Providing sufficient development time and resources to iterate designs to reduce future costs.

j. Maintain competition among contractors and/or alternative systems or subsystems as long as economically justifiable.

k. Tailoring of specifications and standards.

l. Consideration of the use of contract incentives during development and production which motivate the contractor to strive toward lower production costs and support costs.

m. Consideration of contractor maintenance or warranties for early use during the production/deployment phase.

1-2.3 Design Actions

a. Lowering development and acquisition costs through design simplicity, greater use of design inheritance, greater use of standard and commercial products and use of high production volume technology parts.

b. Improving reliability through greater use of proven designs, more design attention to non-random failures, design simplicity, improved quality control, more effective development and test procedures and use of more representative environmental tests.

c. Improving maintainability through improved accessibility, greater support equipment (SE) standardization, improved test procedures, and more design attention to test equipment.

d. Designing equipment to reduce maintenance skills, special training requirements and manpower requirements.

e. Better testing of designs and incorporation of the results in later design iterations.

1-3 Life Cycle Cost Analysis

1-3.1 Definition of Life Cycle Costing

Life cycle costing is defined as the consideration of life cycle cost, or segments thereof, in various decisions associated with acquiring an item or a defense system.[1] The main objective of life cycle costing is to consider ownership (operation, maintenance, support, etc.) cost, as well as development and acquisition cost, in order to provide visibility to total economic consequences of the various design/development and acquisition decisions. Life cycle cost analysis must, therefore, be used to develop proper planning, design/development and program decision guidance.

1-3.2 Role of LCC Analysis with Respect to Design

The design of an item or system has a tremendous impact on development, acquisition and ownership costs. A simpler design will generally result in lower ownership costs and lower acquisition costs. However,

1. AFR 800-11, Life Cycle Costing (LCC).

improving reliability may result in a lower ownership cost, but increased development and acquisition costs. The potential conflict among objectives becomes even more complex when it involves the full spectrum of design objectives. Some of the objectives which must be addressed in evolving a single preferred design include: many aspects of performance, supportability, producibility, vulnerability, survivability, growth potential, safety, reliability, flexibility, maintainability, versatility and self-sufficiency. With all these and many other factors to consider, arriving at a logically balanced and preferred design can be difficult. Schedule constraints make the design task even more difficult.

1-3.3 Scope and Spectrum of LCC Analysis Activities

There are three primary areas of life cycle cost analysis activities. These activities are:

a. Preparation of life cycle cost estimates (development, acquisition and ownership).

b. Use of contract incentive provisions to motivate the contractors to design and produce equipment with low life cycle cost and/or a consideration in awarding the contract, i.e., life cycle cost procurement. Additional guidance on life cycle cost procurement planning and execution is currently being prepared and will be issued under separate cover.[2]

c. Designing to reduce life cycle cost. Rigorous management and sound engineering can significantly influence the evolution of a low life cycle cost design through numerous planning, design, development testing and program decisions associated with all item, system and support system design activities. A guide[3] is available to assist program managers in their efforts to assure that life cycle costs are adequately considered in arriving at design and program decisions.

There are many potential uses of life cycle cost analysis in each of these three primary areas. Specific analysis tasks vary because their results provide information and guidance for different program events that occur throughout the acquisition process. Accomplishment of these tasks requires a team approach. The team should include or get the required inputs from operational, logistics and design personnel, as well as system and cost analysts. It is the responsibility of whomever is in charge of the program at the time, such as the Deputy for

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2. Supplemental Life Cycle Costing Procurement Guide (in preparation).

3. Supplemental Life Cycle Costing Program Management Guidance, March 1975, ASD/ACL.

Development Planning, a SPO Cadre Director, a Prototype Office Director, a Program Office Director, etc., to see that such a team is organized and functioning effectively to accomplish specified life cycle cost analysis tasks.

1-4 Approach and Scope of Guide

The approach taken in this guide is to address life cycle cost analysis in several ways. Following this chapter and Chapter 2, "Overview of the Acquisition Process," Chapter 3 lists for each acquisition phase key program events and supporting activities for which life cycle cost analysis has a role. In Chapter 4, specific LCC analysis tasks are described. These task descriptions include information on differing task objectives and how each specific task should be approached. The analysis tasks vary primarily as a function of the decision issues being addressed, i.e., design, preparation of cost estimates, source selection, etc., and the phase of the acquisition cycle. The descriptive material in this guide for each analysis approach addressed includes, where applicable, guidance on (1) important considerations and inputs, (2) steps and methods, (3) data sources, (4) analysis results, and (5) applicable contractor activities. Chapter 5 describes methods and terms used in life cycle cost analysis. Appendix A provides guidance on the preparation of a Life Cycle Cost Plan. An overview of the Planning, Programming, and Budgeting Process and the relationship to major program decisions is included as Appendix B. Representative life cycle cost models which can be used in specific life cycle cost analysis tasks are discussed in Appendix C. Appendix D contains a bibliography which can be used as a reference to key acquisition program activities related to life cycle cost analysis. A listing of commonly used abbreviations and acronyms is contained in Appendix E.

This guide should be of value to managers in determining and specifying the specific types of analyses needed to address decisions associated with their programs. It should help experienced analysts new to life cycle cost more effectively organize and initiate their analysis efforts.

Chapter 2

System Acquisition Overview

2-1 Objective

The objective of this chapter is to provide an overview of the system acquisition process, from requirements definition through deployment. Emphasis is placed on the description of the major program reviews, decision points, pertinent directives and contract documents. Those unfamiliar with AFR 800-2 methodology and terminology and those new to system acquisition will find this chapter a useful summary of the overall system acquisition process.

2-2 Scope

The methodology described here explains the system acquisition process which a major program may follow based on DOD Directive 5000.1 and AFR 800-2. This is not an inflexible process since OSD/SAF can give latitude in management constraints commensurate with the scope of each program to allow some of the phases to be omitted, run concurrently, or combined.

2-3 System Acquisition Summary

a. Standard system acquisition for major systems is normally divided into five phases (Conceptual, Validation, Full Scale Development, Production, and Deployment/Operating), with each of the first three followed by Secretary of Defense (SECDEF) decisions. The emphasis is on decentralized management tailored for each individual program. Control and rapid response is accomplished by a direct streamlined reporting system called the Blue Line. This Blue Line communications system provides the program manager direct communication to his Command Commander, Chief of Staff, and Secretary of the Air Force. Many decisions and directions are made through this Blue Line system. During the first three phases, the Air Force gathers pertinent Government/contractor data to make program recommendations. For major programs, it supports a request to the Secretary of Defense to proceed. Secretary approval, constraints and basic information furnished by the program office provide the basic information from which the draft Decision Coordinating Paper (DCP) is prepared. On other programs, data provided by program offices supports the preparation of the program/project approval document. After review by the Defense Systems Acquisition Review Council (DSARC), the Secretary of Defense presents his decision by issuing a formal Decision Coordinating Paper. If the decision is to continue the program, restraints and management policy are dictated in the Decision Coordinating Paper.

b. The Conceptual Phase starts with requirements definition. Studies, tests and analyses of experimental hardware development establish the technical, military and economic bases. This effort is called program advocacy and the documentation developed is the advocacy package. The Validation Phase is a refinement of major program characteristics through extensive analysis, further prototype hardware development, test and evaluation. The system and major support equipment are designed, fabricated and tested during the Full-Scale Development Phase to insure the production equipment will meet system objectives in support of a production decision. The time from production approval until the operating command accepts the last operational unit is called the Production Phase. The period from the user's acceptance of the first operational unit until system deactivation or phase out is called the Deployment Phase.

c. The services request Secretary of Defense direction with the draft Decision Coordinating Paper, and the Secretary of Defense directs with the signed Decision Coordinating Paper. Hq USAF directs with a Program Management Directive (PMD) to the major commands (MAJCOMs). The Program Manager (PM) indicates the integrated time-phased tasks and resources required to complete the task specified in the Program Management Directive by his Program Management Plan (PMP).

d. The implementing command (usually AFSC) and the Program Manager usually operate through a System Program Office (SPO) to manage the system acquisition process. Listed below are the subdivisions found in the "standard" System Program Office to provide insight into the functional areas covered by the System Program Office:

(1) Business (Procurement, Financial and Schedule Management).

(2) Engineering.

(3) Configuration Management.

(4) Manufacturing.

(5) Test and Evaluation.

(6) Logistics Support (normally collocated and manned with AFLC and AFSC personnel).

2-4 Conceptual Phase

a. The Required Operational Capability (ROC) document states the operational deficiency or need and is generated normally by Hq USAF or a MAJCOM. It is usually supported by studies called Mission Analyses. Hq USAF reviews the Required Operational Capability and should answer it within 90 days via a Program Management Directive to dictate actions for further investigation or to establish a program. This Program Management Directive usually allows AFSC to create a program priority, establish a SPO cadre, assign a PM and enter into the program advocacy activities.

b. Program advocacy is that effort by Hq USAF and MAJCOMs to assemble the necessary studies and analyses to allow the SECDEF to make a program decision after review of the draft Decision Coordinating Paper. The advocacy package is based on preliminary design, industry assessments, alternatives, studies and analyses, etc., and includes plans on cost, schedule, advance procurement, source selection, test, production, logistics, etc. The System Program Office also develops the work statement(s), request for proposal(s) and the Program Management Plan. The advocacy documentation provides the functional baseline (program requirements baseline) and forms the basis for the Hq USAF draft Decision Coordinating Paper.

c. Contract documents during this phase normally are cost type or fixed price level of effort and contain a few firm technical, cost or schedule requirements. These contracts call for free application of innovations and knowledge for the conceptual description of systems which would satisfy a stated mission. There is little or no hardware involved. As the system definition proceeds, and alternatives are examined and eliminated, early configurations of hardware, usually critical subsystems, are created and tested. Hardware, however, is seldom the most significant product of such contracts. The end item of these contracts is the data which, in the form of studies, analyses, test results and conceptual drawings and specifications, demonstrates that concepts exist which have a high probability of satisfying the mission at an affordable cost in a reasonable time.

d. At OSD, the Director of Defense, Research and Engineering (DDR&E) has primary responsibility for review of the draft Decision Coordinating Paper with the appropriate Assistant Secretaries of Defense prior to the DSARC review. The DSARC is composed of DDR&E and the Assistant Secretaries of Defense for Comptroller, Installations and Logistics and Program Analysis and Evaluation. The Decision Coordinating Paper approved by SECDEF will identify the limits or conditions that accompany his decision and thresholds of cost, schedule and performance which cannot be changed or violated without his approval.

2-5 Validation Phase

a. During the Validation Phase, the program characteristics (performance, cost and schedule) are validated and refined through extensive analysis, hardware development and prototype testing. The goal is to establish an allocated baseline consisting of firm and realistic system, subsystem and configuration item (CI) performance requirements and other design constraints; supporting technical data; and program data. In other words, in the Validation Phase, performance specifications and supporting data are developed to establish a new "design requirements" baseline, called the allocated baseline, which meets the program requirements established as a functional baseline in the Conceptual Phase. Source

selection authority and contracting thresholds to be met are contained in the program decision Decision Coordinating Paper which begins the Validation Phase. However, as is true after receipt of Decision Coordinating Papers in all phases, the expenditure of funds cannot be made until Hq USAF issues funding authority via Budget Authorization and Program Authorization (BA and PA).

b. During this phase, hardware assumes a much greater importance as a means of verifying and defining design and engineering concepts, risk reduction and trade-offs. DOD policy requires that models, prototypes, mock-ups and system hardware and testing thereof will be used so that any decision to proceed further is based upon tested performance of system hardware and upon cost data reflective of actual fabrication results. Competition among two or more concepts and contractors is accomplished whenever resources are sufficient. Competition is normally for technical innovations but is also used as the basis for obtaining cost reductions when the item is within the state of the art and relatively low in risk. Competition is particularly important in this phase whenever it will be uneconomical to continue competition into full scale development. In these cases, the concept and contractor selected will be those that will continue into initial production and, in many cases, will also be the only ones feasible for full production and deployment. Thus, the assessments to be made must address both the suitability of the concepts and capabilities of the proposed contractors. Testing of operational prototypes is accomplished whenever feasible. When it is not feasible to test complete prototypes, alternatives, such as testing prototypes of major subsystems and competitive development of hardware, are considered.

c. The major objectives of this phase are to reduce technical, cost and schedule risks, to accomplish more detailed planning, to resolve or minimize logistics problems, and to prepare formal requirement documents that translate the requirements into a solicitation package for full scale development. Thus, contracts for the Validation Phase should assure the acquisition of sufficient data rights to allow the Government the use of all development efforts in the succeeding Full Scale Development Phase. Cost reimbursement type contracts are usually selected based on the consideration of risk and the fact that the contract normally requires "best efforts" only.

d. The total effort of the Validation Phase is to optimize the system design based on system performance and cost, to specify in the allocated baseline the performance desired to the configuration item level, to leave as little risk as possible for full scale development and to document all this in the draft Decision Coordinating Paper to be used for the ratification decision by SECDEF.

2-6 Full Scale Development Phase

a. The system, including support items, is designed, fabricated and tested during this phase. The intended output is, as a minimum, a preproduction system which closely approximates the final products, the documentation necessary to enter the Production Phase and test results which meet the requirements.

b. Direction comes to AFSC in the Ratification Decision Decision Coordinating Paper, the resulting Hq USAF Program Management Directive and the Hq USAF Budget Authorization and Program Authorization. Source selection of a contractor is very important due to the importance and magnitude of the effort and is usually reviewed at a high level. The contract(s) for this phase should take the design and/or product of the Validation Phase and further develop it for operational use with as low a cost in production as possible without unduly sacrificing quality, and with full consideration of life cycle cost. In those cases where Validation Phase activities have lowered the risks to an acceptable level, contracts often consider the inclusion of not-to-exceed option prices (with economic price adjustment provisions) for initial production quantities. Alternative approaches include using a provision in the full scale development contract, which bases a portion of the production contract profit or fee on the degree of success in achieving the Design to Cost goal, and including an incentive in the development contract, based on the degree of success in meeting the Design to Cost goal and/or life cycle cost target.

c. The contractor design activity starts from the performance specification (allocation baseline) and develops detail drawings, interface control drawings, assembly drawings, installation drawings and Part II Product Specifications. The Air Force controls configuration through the Configuration Control Board (CCB) which evaluates and approves/disapproves system and configuration item specification changes.

d. Design verification reviews are scheduled to assess the status of technical efforts. These verification reviews are extremely significant and are scheduled in the Program Management Plan. The Preliminary Design Review (PDR) is conducted prior to commencing with the detailed design process to assure that the approach is feasible and sound from a design, development, test and activation viewpoint. The Critical Design Review (CDR) should be performed prior to the start of system level development, test and evaluation (DT&E) to assure that the detail design adequately satisfies the requirements contained in Part I of the Development Specifications and to allow the PM to formally approve the design of the equipment to be tested. The Production Readiness Review (PRR) is conducted to provide data for Air Force management to prepare the draft Decision Coordinating Paper for the production decision.

e. The conduct of Development Test and Evaluation by the Air Force and contractors under firm direction and control of the Air Force is an essential activity during the Full Scale Development Phase. The Air Force team is headed by the Program Manager or his designated representative, but maximum operational command, AFLC and ATC participation is encouraged. Planning with these organizations and industry is stepped up for the Initial Operational Test and Evaluation (IOT&E) to be conducted by the operating command prior to the production decision. As qualification tests are completed for each configuration item, subsystem or system, a formal examination is held to verify that the item has achieved the performance specified in its functional or allocated baseline. This examination is called the Functional Configuration Audit (FCA).

f. During the full scale development process, emphasis must be placed on reducing technical risks and establishing confidence that an item of equipment or a system will function in the intended environment. This concept, which may be called "Fly-Before-You-Buy," is used to provide a balance between development and production that will produce a system with the desired hardware and capability at an acceptable risk level. The completion of well organized verification reviews and functional configuration items can fulfill this goal and provides the Air Force with sufficient information for the production decision draft Decision Coordinating Paper.

2-7 Production Phase

a. The Decision Coordinating Paper following production decision provides direction for system production. The production contractor need not be the one used during previous phases, and usually high-level source selection approval is designated in the Decision Coordinating Paper. The Program Manager maintains his program management responsibilities to produce and deliver an effective and supportable system at a prescribed cost; however, detailed contract administration is primarily performed by the appropriate Air Force Plant Representative (AFPR) or Defense Contract Administration Services (DCAS) in-plant representatives. Control of the factors of production (manpower, materiel and real property facilities), quality and finished property inventory is required. Development, Test and Evaluation may continue during the early Production Phase.

b. During this phase, fixed price contracts are often used. Whenever feasible, the initial production is a pilot quantity which is used to verify the design and to provide a sound basis for subsequent production. In view of the scale of production contracts for major systems, particular attention must be given to the realism of delivery requirements, warranty provisions and all special provisions including Support Cost Commitments, Price Adjustment, Operating and Support Cost Incentives and Life Cycle Cost Verification Tests.

c. The Physical Configuration Audit (PCA) is a significant production milestone whereby the configuration of an early production unit (usually out of the first lot) is carefully compared to the design and production drawings. The product of the Physical Configuration Audit is formal Program Manager's acceptance of the Part II Product Specifications as audited and approved documents which satisfy the contractual obligation. The Physical Configuration Audit provides the Production Baseline, is the prerequisite to configuration item acceptance, marks the beginning of formal engineering change control for Class I hardware design changes, and is usually required for the start of Follow-On Operational Test and Evaluation (FOT&E) by the using command.

2-8 Deployment Phase

The system is accepted for operation and maintenance by the using command during the Deployment Phase. Acceptance of the first operating unit establishes the significant milestone known as "turnover." Program Management Responsibility Transfer (PMRT) is the transfer of all system management, engineering, funding and procurement responsibility from AFSC to AFLC. The date for Program Management Responsibility Transfer will be determined by AFSC and AFLC during the full scale development phase and forwarded to Hq USAF for inclusion in the production Program Management Directive. Program Management Responsibility Transfer will occur at the earliest practicable date during the production phase. Significant planning and coordination between Hq USAF, AFSC, AFLC and the using command throughout the entire acquisition process is required to effect a proper turnover and Program Management Responsibility Transfer. Unless AFSC and AFLC jointly agree or are directed otherwise, AFSC must complete the following milestones prior to Program Management Responsibility Transfer.

a. Development Testing complete.

b. Product Baseline (PCA) established.

c. All update (development) engineering changes on contract.

d. Appropriate AFLC data (drawings, technical orders, etc.) available.

Chapter 3

Acquisition Program Events and Activities Related to Life Cycle Cost Analysis

3-1 Objective

Chapter 2 contained summary descriptions of each phase of the Acquisition Process. Other sources including AFLCM 800-1 and AFSCP 800-3 identify and describe the many events and activities involved in considerable detail. The primary purpose of Chapter 3 is to show the relationship between the specific life cycle cost analysis tasks described in Chapter 4 and life cycle cost related acquisition activities and the Defense Systems Acquisition Review Council information requirements. In planning life cycle cost analysis tasks, one should make the accomplishment of the listed acquisition activities an integral part of the life cycle cost analysis, wherever possible. Completed activities should also be used as sources of information for future life cycle cost analysis tasks. Caution should be taken in that the list of activities is general and does not indicate mandatory requirements on all programs.

Some of the life cycle cost analysis tasks described in Chapter 4 include one or more of the activities listed in Chapter 3. Sections 3.2 through 3.5 list the life cycle cost analysis related activities. These activities have been grouped by phase and by event. Section 3.6 identifies the information required by the DSARC and shows its relationship to the program events and the specific life cycle cost analysis tasks described in Chapter 4.

3-2 Conceptual Phase Program Events and Activites Related to Life Cycle Cost Analysis

3-2.1 Draft Required Operational Capability (ROC)

Establish Operational and Preliminary Maintenance Concepts
Establish Preliminary Support Concept
Perform Preliminary Reliability and Maintainability (R&M) Trades
Perform Preliminary Life Cycle Cost Trades

3-2.2 Final ROC

Establish System Availability Requirements
Establish Maintenance Concept and Proposed Levels of Maintenance
Establish Reliability and Maintainability Requirements and Goals

3-2.3 Advocacy Package

Review Lessons Learned Experience from Similar Systems or Programs
Determine Preliminary Logistic Support Analysis (LSA) Inputs
Determine Logistics Concept
Perform Life Cycle Cost Trade-Offs (Requirements, Design Approach, Operational Concept, Support Concept)
Determine Design to Cost Goals and Life Cycle Cost Estimates
Prepare Advanced Procurement Plan Addressing Design to Cost, Life Cycle Cost, Reliability and Maintainability Requirements and Goals, Warranties, Guarantees and Incentives
Develop Life Cycle Cost Model(s)

3-2.4 Decision Coordinating Paper (DCP)

Review Design to Cost/Life Cycle Cost Trade Study Results and Plans
Review Design to Cost Goals
Update Reliability and Maintainability Requirements and Goals
Prepare Cost of Ownership Assessment

3-2.5 Independent Cost Analysis (ICA)

Prepare Independent Estimates of Acquisition and Ownership Costs of Approved Program and all Alternatives to be Presented to the DSARC
Compare Independent Cost Analysis Team and Program Office Estimates and Prepare Variance Analysis
Compare Proposed System(s) and Current System(s) Support Costs
Assess Feasibility of Attaining Design to Cost Goals

3-3 Validation Phase Program Events and Life Cycle Cost Analysis Related Activities

3-3.1 Program Management Plan (PMP)

Update and Document in Detail How Life Cycle Costing will be Applied to the Program
Determine and Describe Role of Testing in Achieving Life Cycle Cost Objectives
Determine and Describe Role of Design to Cost in Achieving Life Cycle Cost Objectives
Determine and Describe Role of Incentives, Guarantees and Warranties in Achieving Life Cycle Cost Objectives

3-3.2 System Specification

Identify Design Characteristics with Significant Impact on Life Cycle Cost
Ensure Use of Design Feedback from Lessons Learned on Other Programs
Accomplish Extensive Life Cycle Cost Design Trade Studies
Establish a Preliminary List of Government Furnished Equipment (GFE) and Contractor Furnished Equipment (CFE)

3-3.3 Statement of Work (SOW)

Develop Guidelines for Use of Life Cycle Cost Models
Employ a Life Cycle Cost Model to Identify Important Design Parameters and Trade-Offs
Establish Required Life Cycle Cost Design Trade-Offs
Finalize Life Cycle Cost Models to be Used by the Contractor
Establish Life Cycle Cost Related Incentives and Evaluation Criteria
Identify Logistics Support Analysis Requirements and Government Inputs for Contractor Analysis
Develop Precise Definitions of MTBF, Failure, Operating Time and Other Life Cycle Cost Parameters and Establish Data Collection, Evaluation and Reporting Procedures
Establish Life Cycle Cost Related Performance, Design and Demonstration Requirements
Establish Total Life Cycle Cost Breakdown Structure, Compatible with the Contract Work Breakdown Structure

3-3.4 Contract Data Requirements List (CDRL)

Ensure Availability and Adequacy of Required Life Cycle Cost Data
Prepare Required Data Item Descriptions

3-3.5 Request for Proposal (RFP)

Prepare Detailed Instructions on Cost Data, Trade-Off Studies, Warranty, Guarantee and Incentive Provisions
Clearly Convey How Life Cycle Cost and Life Cycle Cost Models will be used in Source Selection
Prepare Life Cycle Cost Verification Test Plans

3-3.6 Source Selection Decision

Review Performance Requirements Including Reliability, Maintainability and Availability
Review Support Concept
Review Life Cycle Cost and Logistics Support Cost Models and Data Submitted by Contractor
Evaluate Life Cycle Cost Impact on Each Proposed Design
Evaluate Proposed Level of Repair, Skill Levels, Depot/Repair Facilities, Support Equipment
Evaluate Response to Warranty and Incentive Provisions

3-3.7 Decision Coordinating Paper (DCP)

Review Life Cycle Cost Trade-Off Results and Plans
Assess Reliability and Maintainability Requirements and Their Potential Impact on Design to Cost and Life Cycle Cost
Review Test and Evaluation Results and Plans Related to Life Cycle Cost
Reassess Design to Cost and Life Cycle Cost Achievements and Projections
Update Cost of Ownership Assessment

3-3.8 Independent Cost Analysis (ICA)

Prepare Independent Estimates of Acquisition and Ownership Costs of Approved Program and All Alternatives to be Presented to the DSARC
Compare This Independent Cost Analysis to Previous Independent Cost Analysis and Perform Variance Analysis
Compare the Independent Cost Analysis to the Program Office Estimates and Prepare a Variance Analysis
Compare Proposed System and Current System(s) Support Costs
Assess Validity of Design to Cost Goals

3-4 Full Scale Development Phase Program Events and Life Cycle Cost Analysis Related Activities

3-4.1 Program Management Directive (PMD)

Update Direction Regarding Design to Cost, Life Cycle Cost, Reliability and Maintainability, Warranties, Guarantees and Incentives

3-4.2 Program Management Plan (PMP) Update

Update Procurement Plan
Update Test Plans
Update Logistics Support Analysis
Identify Life Cycle Cost Trade-Offs
Identify Life Cycle Cost Sensitive Issues to be Tracked and Addressed in Command Assessment Reviews and Program Assessment Reviews

3-4.3 Preliminary Design Review (PDR)

Review Common and Peculiar Support Equipment Plans and Decisions
Review Contractor Furnished Equipment and Government Furnished Equipment Decisions
Review Design for Compatibility with Logistics Support Concept
Assess Use of Lessons Learned and Historical Support Cost Data to Identify Potential Design Problems Impacting Life Cycle Cost
Assess Test Results and Their Life Cycle Cost Implications
Review Reliability and Maintainability Status and Potential Problems

3-4.4 Other Design Reviews

Determine Life Cycle Cost Impact of Proposed Design Changes
Verify the Life Cycle Cost Implications of Proposed Design Changes by Assessing Integration in Logistics Support Analyses and Optimum Repair Level Analyses

3-4.5 Subsystem Testing

Assess Test Results for their Implications with Respect to Achieving Reliability and Maintainability and Other Life Cycle Cost Related Objectives

3-4.6 Critical Design Review (CDR)

Update Design to Cost and Life Cycle Cost Estimates Based on Evaluation of System
Identify Potential Design/Support Problems

3-4.7 System Testing

Assess Test Results with Respect to Achieving Reliability and Maintainability and Other Life Cycle Cost Related Objectives
Update Life Cycle Cost Estimates

3-4.8 Establishment of Baseline Configuration

Assess Design Review Changes for Impact on Performance, Life Cycle Cost and Design to Cost Goals
Determine Total Life Cycle Cost Impact of Baseline Configuration Design Decisions
Establish Baseline Configuration Life Cycle Cost Estimate

3-4.9 Production Request for Proposal (RFP)

Develop Detailed Instructions for Life Cycle Cost Related Information Submission
Update and Document Planned Use of Warranty, Guarantee and Incentive Contract Provisions

3-4.10 Decision Coordinating Paper (DCP)

Review Life Cycle Cost Trade-Off Results and Plans
Update Reliability and Maintainability Impact Relative to Design to Cost and Life Cycle Cost
Review Test and Evaluation Results and Plans Related to Life Cycle Cost
Reassess Design to Cost and Life Cycle Cost Achievement and Projections
Update Cost of Ownership Assessment

3-4.11 Independent Cost Analysis (ICA)

Prepare Independent Estimates of Acquisition and Ownership Costs of Approved Program and Alternatives to be Presented to the DSARC
Compare this Independent Cost Analysis to Previous Independent Cost Analyses and Prepare Variance Analysis
Compare this Independent Cost Analysis to Program Office Estimates and Prepare Variance Analysis
Assess Validity of Design to Cost Goals

3-5 Production Phase Program Events and Life Cycle Cost Analysis Related Activities

3-5.1 Program Management Direction (PMD)

Update Direction Regarding Design to Cost and Life Cycle Cost Objectives and Reliability and Maintainability Requirements

3-5.2 Program Management Plan (PMP) Update

Revise to Update Any New Life Cycle Cost Direction

3-5.3 <u>Verification Reviews</u>

Evaluate for Conformance to Life Cycle Cost Objectives with Emphasis on Reliability and Maintainability
Review and Analyze Results of Additional Development, Test and Evaluation, Production Qualification and Acceptance Tests
Refine Life Cycle Cost Estimates

3-5.4 <u>Engineering Change Proposals (ECPs)</u>

Determine Life Cycle Cost Impact of Proposed Changes
Verify the Life Cycle Cost Implications of Proposed Design Changes by Assessing Integration in Logistic Support Analyses and Optimum Repair Level Analyses

3-5.5 <u>Life Cycle Cost Verification Testing</u>

Determine Reliability and Maintainability Support System Characteristics and Parameters Identified in the Contract
Evaluate Life Cycle Cost or Logistics Support Cost in Accordance with Procedures Specified in Contract

3-6 <u>DSARC Determinations and Their Relationships to Program Events and Specific Life Cycle Cost Analysis Tasks</u>

3-6.1 <u>Introduction</u>. This section contains three sets of DSARC review determinations, one each for DSARC I, DSARC II and DSARC III, respectively. Following each set is a table identifying each of the determinations that must be supported by life cycle cost analysis, a reference to the key program events identified in previous sections of this chapter and a reference to specific life cycle cost analysis tasks that are described in Chapter 4.

3-6.2 <u>General</u>. The Decision Coordinating Paper (DCP) and the Defense Systems Acquisition Review Council (DSARC) process involves decision making at the Secretary of Defense level on major defense system acquisition programs and related policies. The Decision Coordinating Paper documents the current or proposed program and serves as the basis for DSARC reviews. It is the principle document for recording (1) the essential information on a program, e.g., need/threat, concept, milestones, thresholds, issues and risks, alternatives, management plan, supporting rationale for the decisions and affordability in terms of projected budget and phasing of out-year funding; and (2) the Secretary of Defense decisions. Guidelines for preparation and processing of the Decision Coordinating Paper are contained in DOD Instruction 5000.2. Approval to proceed to the next phase, e.g., validation, full scale development or production, is accomplished through this formal DOD

management and decision-making system. The DSARC reviews serve to complement the Decision Coordinating Paper. The DSARC recommendations are based on the determinations that are identified in subsequent paragraphs. Major program decisions are also made in the context with the Planning, Programming, and Budgeting System (PPBS). In the PPBS, the Secretary of Defense decision on individual programs is keyed to the problem of balancing all programs within the DOD fiscal limits. The program covered by a Decision Coordinating Paper must fit into this affordability category. When an OSD-generated PPBS document, such as the Issue Paper or Program/Budget Decision (PBD), offers an alternative to the Decision Coordinating Paper/DSARC-related decision, the Decision Coordinating Paper must be updated or amended to reflect the change and to reference the appropriate decision document. An overview of the Planning, Programming, and Budgeting System is contained in Appendix B.

3-6.3 The DSARC I Review (Program Initiation). DOD Directive 5000.26 directs that, at the DSARC I review leading to the program initiation decision, the following be determined:

a. A potential military need exists for a new Defense System or an improved system.

b. The military requirements properly relate to the mission, the threat and force obsolescence.

c. Alternate defense systems that will satisfy the military need, including system modernizations and foreign developments, have been considered along with anticipated resources for resolving the need.

d. Broad mission/performance requirements/specifications are adequately defined (technically) and are economically plausible.

e. Anticipated quantity, resource and schedule estimates are realistic and acceptable in context with affordability limits. The appropriate acquisition (e.g., planning estimates) and ownership cost estimates have been validated by independent assessment. (OSD Cost Analysis Improvement Group.)

f. Major programs, issues and risks are identified, and suitable methods for their resolution, such as the use of prototypes, are planned.

g. The statements of questions and issues and of test objectives and schedules are adequate.

h. Critical logistics support factors and facilities impacts have been identified.

i. Future support costs, including a comparison with those of current systems, have been considered.

j. The use of currently available subsystems versus development of new subsystems has been or will be considered.

k. Economic and technical competition to the maximum extent feasible is planned.

l. Program thresholds in the Decision Coordinating Paper are appropriate, well defined and provide the flexibility for accomplishing identification of significant problems.

m. Practical trade-offs have been made between performance, risk, cost and schedule.

n. The acquisition strategy, including type of contract, is consistent with program characteristics and risks.

o. Possible alternative fall-back position(s) are available in the event the proposed approach to the program is unsuccessful.

p. Design to cost goals, related reliability and maintainability goals and associated thresholds are established.

q. Requisites for transition to full-scale engineering development have been established.

r. The program plan for this phase is adequate.

TABLE 3-1
DSARC I DETERMINATION/CONCEPT PHASE PROGRAM EVENT/
SPECIFIC LIFE CYCLE COST ANALYSIS TASK RELATIONSHIPS

DSARC I DETERMINATIONS	CONCEPTUAL PHASE PROGRAM EVENTS	SPECIFIC LCC ANALYSIS TASKS
3-6.3d	3-2.1, 3-2.2, 3-2.3	4-2.1
3-6.3e	3-2.5	4-2.3, 4-2.4
3-6.3h	3-2.3, 3-2.4	4-2.2
3-6.3i	3-2.3, 3-2.4, 3-2.5	4-2.3, 4-2.4
3-6.3j	3-2.3	4-2.2
3-6.3m	3-2.3	4-2.1
3-6.3n	3-2.3	4-2.5
3-6.3p	3-2.4	4-2.2
3-6.3r	3-2.3	4-2.6

3-6.4 The DSARC II Review (Full Scale Development). DOD Directive 5000.26 also directs that, at the DSARC II review leading to the full scale development decision, the following be determined:

a. The defense system still satisfies the military need, and the requirements properly relate to the mission, the threat and anticipated resources - considering changes that have occurred since the previous Secretary of Defense decision.

b. System trade-offs have produced a proper balance between cost, schedule and performance, including reliability and maintainability.

c. Quantity, resource and schedule estimates are realistic and acceptable. Relative cost estimates of support and operations have been evaluated (e.g., 10 year cost). Cost estimates for both acquisition and support have been validated by independent assessment (OSD Cost Analysis Improvement Group).

d. Major uncertainties and risks have been reduced to acceptable levels, and effective methods are identified to resolve residual uncertainties and risks.

e. The proposed system is cost effective compared with competing alternative ways of satisfying the military need.

f. Valid design to cost goals are established.

g. Program thresholds in the Decision Coordinating Paper are appropriate and well defined.

h. The approach for selection of major subsystems has been clearly identified, and the program has considered the use of currently available subsystems versus new development (including test and support equipment).

i. The development and operational test and evaluation already conducted have progressed satisfactorily, and the future test program proposed (e.g., objectives, plans and schedules) is sound.

j. An integrated test and evaluation plan has been prepared which identifies all T&E to be accomplished and ensures that all necessary T&E is accomplished prior to the decision points.

k. The program management structure and plan are sound.

l. Maximum practical use of competition has been incorporated in the acquisition plan.

m. The acquisition strategy, including contract type, is consistent with program characteristics and risk.

n. The proposed fall-back position(s), if any, have been reassessed and found suitable.

o. Requisites for the production/deployment decision, including logistics support, have been established.

TABLE 3-2
DSARC II DETERMINATION/VALIDATION PHASE PROGRAM EVENT/
SPECIFIC LIFE CYCLE COST ANALYSIS TASK RELATIONSHIPS

DSARC II DETERMINATIONS	VALIDATION PHASE PROGRAM EVENTS	SPECIFIC LCC ANALYSIS TASKS
3-6.4b	3-3.2, 3-3.3, 3-3.6, 3-3.7	4-3.1
3-6.4c	3-3.8	4-3.2, 4-3.3
3-6.4e	3-3.7, 3-3.8	4-3.2, 4-3.3
3-6.4f	3-3.7, 3-3.8	4-3.3
3-6.4h	3-3.6, 3-3.7	4-3.1
3-6.4k	3-3.5	4-3.6
3-6.4m	3-3.1, 3-3.3, 3-3.5	4-3.4, 4-3.5

3-6.5 The DSARC III Review (Production). DOD Directive 5000.26 also directs that, at the DSARC III review leading to the production decision, the following be determined:

a. The defense system still satisfies a military need, and its performance properly relates to the mission, the threat, the planning and policy guidance and anticipated resources - considering changes that have occurred since the previous Secretary of Defense decision.

b. Test results based on development test and evaluation (DT&E) and initial operational test and evaluation (IOT&E) are adequate to support a decision to proceed with major production, and plans and schedules for remaining testing are adequate.

c. Quantity, resource and schedule estimates are still realistic and acceptable. Relative cost estimates of support and operation have been evaluated (e.g., 10 year cost) where relevant. The cost estimates for both acquisition and support have been validated by independent assessment (OSD Cost Analysis Improvement Group).

d. The defense system is cost effective for both acquisition and support compared with competing alternative ways of satisfying the military need.

e. System trade-offs have produced a proper balance between cost, schedule and performance, including reliability and maintainability.

f. Program thresholds in the Decision Coordinating Paper are well defined.

g. Production quantity requirements are valid.

h. Issues concerning production, logistics support, facilities and maintenance are identified, and plans for their resolution are sound.

i. The program management structure and plan are sound.

j. All major problems have been revealed, and solutions to residual risks have been identified.

k. The acquisition strategy and contract plan are consistent with program characteristics and risks, and the approach to contractor selection is sound. The proposed contract type and options, if any, provide DOD flexibility for increasing or decreasing the production rate and total quantity.

l. Requisites for future production decisions have been defined, and competition (e.g., second source and/or breakout) has been considered.

m. The plan for transition to production and deployment is adequate including integration with existing operational systems.

TABLE 3-3
DSARC III DETERMINATION/FULL SCALE DEVELOPMENT PROGRAM EVENT/ SPECIFIC LIFE CYCLE COST ANALYSIS TASK RELATIONSHIPS

DSARC III DETERMINATIONS	FULL SCALE DEVELOPMENT PROGRAM EVENTS	SPECIFIC LCC ANALYSIS TASKS
3-6.5c	3-4.10, 3-4.11	4-4.2, 4-4.3
3-6.5d	3-4.10, 3-4.11	4-4.2, 4-4.3
3-6.5e	3-4.8, 3-4.10	4-4.1
3-6.5k	3-4.9	4-4.4

Chapter 4

Specific Life Cycle Cost Analysis Task Descriptions

4-1 Objective

This chapter contains selected life cycle cost analysis task descriptions. These analysis tasks can be accomplished individually or as a part of an integrated effort to implement a Program Life Cycle Cost Plan. Appendix A contains guidance on the preparation of a Program Life Cycle Cost Plan. Each task description includes a discussion of analysis objectives and a proposed study approach. The approach material addresses important considerations and inputs, steps and methods, data sources, desired analysis results and applicable contractor activities. Certain analysis methods mentioned in Chapter 4 are underlined, indicating that this method is described in more detail in Chapter 5.

Decisions and, therefore, analysis needs will vary from program to program. Therefore, these analysis tasks should not be viewed as mandatory or all that may be required for any specific program. This guidance should aid in preparing specific analysis plans to meet the requirements of the program involved. Some of the tasks are iterative and may have to be updated or essentially repeated periodically as new data or guidance becomes available.

4-2 Conceptual Phase Analysis Tasks

4-2.1 Life Cycle Cost Implications of Requirements

a. Objectives. The primary objectives of this analysis are: (1) to identify those aspects of the requirements which drive life cycle costs; (2) to detect significant cost differences among performance level alternatives; (3) to identify major uncertainties with respect to requirements, capabilities and costs; and (4) to use this information to arrive at a set of requirements which attempt to properly balance cost, performance and schedule constraints.

b. Approach

(1) Important Considerations and Inputs

(a) The nature and relative importance of performance objectives in achieving military objectives (such as, speed, range, and payload).

(b) The nature and relative importance of operational requirements (mission scenarios, operating environment and deployment concept) and impact on support alternatives (mobility, basing concepts, support concepts).

(c) The nature and relative importance of resource limitation objectives (such as, desired Initial Operational Capability (IOC) date and maximum unit cost).

(2) Steps and Methods

(a) Search for performance parameters and operational requirements which significantly affect life cycle costs and identify major areas of uncertainty.

(b) Quantify, when possible, the relationship identified in step (a), using new or available Cost Estimating Relationships (CERs) and parametric studies, the judgements of experienced personnel and historical field support data.

(c) Conduct sensitivity analysis to develop an overall understanding of how life cycle costs vary as a function of performance parameters and how uncertainty about these relationships could influence requirements selection.

(d) Develop and apply a set of criteria to screen alternatives to identify a preferred set of requirements, using cost effectiveness or economic analysis techniques.

(e) Organize and present analysis results in a manner designed to most effectively convey all the insights gained to decision makers, rather than presenting a single recommendation.

(3) Data Sources

(a) Past planning studies on related systems or equipments which may be available from AFSC development planning organizations, AFLC and the using command.

(b) Expert judgement from Government and industry specialists on how performance requirements affect design requirements which in turn affect life cycle costs.

(c) Historical acquisition and ownership cost data. Such data is compiled in AFR 173-10, USAF Cost and Planning Factors. The information is in the form of data and procedures with which to forecast costs for most current systems.

(4) Analysis Results

(a) Identification of alternatives.

(b) Quantitative, where possible, but at least the qualitative life cycle cost implications of identified alternatives. This information should be broken out to the third Work Breakdown Structure (WBS) level where possible, i.e., airframe, propulsion system and avionics.

(c) Performance requirements and goals with supporting rationale and a description of their selection criteria.

(d) Areas of uncertainty where further consideration or subsequent studies are required.

(5) Contractor Activities

(a) Preliminary design studies by contractors may be necessary to define performance and design alternatives so that meaningful life cycle cost analyses can be accomplished.

(b) If in-house capabilities are not available, a research study contract may also be needed to develop selection criteria and analyze alternatives.

4-2.2 Determining the Best Employment Concept, Support Concept and System Concepts and Performance Characteristics

a. Objective. The primary objective of this analysis is to support decisions concerning alternative employment concepts, support concepts and system design and performance characteristics (including reliability and maintainability).

b. Approach

(1) Important Considerations and Inputs

(a) The nature of each phase of the system's mission including the mission's duration and operating environment.

(b) The results of mission analysis studies.

(c) The requirements as stated in the Required Operational Capability (ROC).

(d) Using and supporting command personnel knowledge and expertise.

(2) Steps and Methods

(a) Plan the analysis approach based on the following considerations:

1. The operational concept establishes constraints for the maintenance concept.

2. A proposed operational concept must be compatible with the projected maintenance concept and together form the employment concept.

3. The employment concept together with a compatible support concept forms the basis for all logistics planning.

4. The system concept is a result of combining perceived technological opportunities with an employment concept which is believed necessary and sufficient to meet a military objective. Systems concepts must be consistent with attainable employment and support concepts. Determination of preferred system concepts is an iterative process which begins with a clear statement of the objective. It includes an identification of alternative solutions; development of criteria for choice; development or selection of appropriate methods for predicting the relative effectiveness and costs of the alternatives, including the identification of major uncertainties in such predictions; preliminary selection of preferred systems; examination of the sensitivity of the choice to the major assumptions; and reexamination of all major factors which are questionable at that point.

(b) Determine what constitutes satisfactory operation during each phase of the mission.

(c) Analyze the desired operational and support capabilities to determine a desirable level of system availability in terms of mean time between maintenance tasks (MTBMT), mean time to repair (MTTR), turn around time and acceptable unscheduled maintenance rate. The definition of the maintenance method and description of the operating environment must be sufficiently adequate to ensure valid determination of these values.

(d) Compare desired capabilities with experience data from similar systems and with newer techniques.

(e) Conduct gross system trade-offs to develop quantitative operational goals and requirements.

(f) Analyze the maintenance capabilities of the operating forces to determine the applicability to the Required Operational Capability (ROC).

(g) Where current capabilities conflict with stated requirements, conduct a trade-off analysis, considering the development of a new maintenance capability or changes to requirements.

(h) Prepare preliminary support requirements estimates. Key factors that should be considered are quantitative and qualitative personnel requirements, support and test equipment, supply support concepts, facilities, deployment periods and locations, transportation and packaging implications.

(i) Analyze various maintenance concepts to determine the best tentative approach considering the results of reliability and maintainability trade-offs and life cycle costs.

(j) Select the method for deriving qualitative and quantitative reliability and maintainability requirements and goals. One of the more significant available models for evaluating weapon system reliability, availability and cost is described in Appendix C (Section IV.A). Also described in Appendix C is a model for trading off system reliability, performance and cost (Section IV.V); a statistical relationship for estimating the cost of reliability programs (Section III.C); and a simplified maintenance cost model (Section I.D.).

(3) Data Sources

(a) Mission analyses and past studies on related equipment which may be available from the using command, AFLC and AFSC development planning and engineering organizations.

(b) Historical data.

(c) Expert judgement from government and industry specialists who are familiar with the system or equipment.

(4) Analysis Results

(a) A well documented and supportable baseline operational concept.

(b) An employment concept and compatible support concept.

(c) A system concept with realistic availability, reliability and maintainability requirements and goals which, if achieved, are consistent with stated cost-effectiveness or life cycle cost goals.

(d) The criteria and framework for evaluating reliability requirements and goals during the design and test and evaluation process.

(e) The criteria and framework for evaluating the impact on life cycle cost for major design changes, modifications or engineering change proposals.

(f) The criteria for identifying subsystem or major components which will provide the greatest cost effectiveness benefits through reliability improvement.

4-2.3 Cost of Ownership Assessment

a. Objective. The objective of this cost of ownership assessment is to assess the potential operating and support cost impact and provide a basis for tracking these costs as the system evolves during development. On major programs, the initial cost of ownership estimate should be prepared by the Program Office in support of the program initiation decision (DSARC I) and updated at major milestones thereafter.

b. Approach

(1) Important Considerations and Inputs

(a) Program documentation.

(b) Historical data.

(c) Cost Estimating Procedures (AFSCM 173-1).

(d) Cost Analysis Cost Estimating Model (AFR 173-10).

(e) Test and Evaluation Guidance (AFLCM 800-1, Chapter 24).

(2) Steps and Methods

(a) Understand the general program characteristics, such as the level of activity, number of operating locations and number of unit equipments.

(b) Identify analogous systems.

(c) Obtain and evaluate data.

(d) Perform a Cost Analysis Cost Estimating (CACE) model type estimate.

(3) Data Sources

(a) Analogous system cost, design and performance data.

(b) USAF Cost and Planning Factors (AFR 173-10).

(4) Analysis Results

(a) A description of the baseline used for the cost of ownership estimate including the operational scenario and maintenance concept.

(b) A statement of confidence in the values presented and any unusual calculations.

(c) Cost of ownership estimates to support various program decisions and program reviews to (1) track and assess the impact of changes in requirements, design or system capability; (2) provide a basis for determining if potential costs are within anticipated funding levels; (3) assist in determining a proper balance between cost, schedule and performance; and (4) provide a basis for cost trade-off analyses.

(d) A basis for the cost of ownership assessment to be included in the Decision Coordinating Paper.

4-2.4 Preparation of Independent Cost Analysis (ICA) for DSARC I

a. Objective. The objective of this Independent Cost Analysis is to support the program initiation decision process by providing (1) an independent estimate of acquisition and ownership cost estimates of the latest approved program and all alternatives that will be presented to the DSARC; (2) a comparison to the official program office estimates, including the cost of ownership estimate, with supporting variance analysis; (3) a comparison of future support costs with those of current systems; and (4) an assessment of the feasibility of attaining the design to cost goals.

b. Approach

(1) Important Considerations and Inputs

(a) Hq USAF criteria provided in the tasking order.

(b) Program documentation.

(c) Historical data.

(d) Cost Estimating Procedures (AFSCM 173-1).

(2) Steps and Methods

(a) Understand the system. Sufficient knowledge must be obtained on all facets of the system that impact life cycle cost. Among these are the operational concept including mission profiles, the

support concept including the maintenance concept, system and support configurations, physical and performance characteristics, organizational and training concepts, implementation and installation concept, technology involved, test programs, production quantities and schedules. Understand how the program and system significantly differ from past programs.

(b) Acquire background information. Determine and document events leading up to the decision to seek program initiation approval; identify analogous systems; and review related management guidance and direction.

(c) Identify ground rules and assumptions and document where specific guidance is lacking. Address the use of Government Furnished Equipment (GFE) or Contractor Furnished Equipment (CFE), the level of the work breakdown structure to be used to estimate costs, the time phasing of estimates including the number of years of operating and support costs to be figured, and the required use of inflation rates and learning curves. The development estimate should address schedules, test program, number of test articles, static fatigue articles, etc. The operating and support estimate should address the operational concepts, force size, crew ratio, crew composition, number of personnel per squadron, number of flying hours per squadron per year, etc. The program manager should review and coordinate on all ground rules and assumptions.

(d) Select the estimating method. The use of parametric costing techniques should be used, whenever appropriate. Cost Estimating Relationships which are already available or which can be developed from cost, performance and/or physical characteristics data on analogous weapon systems should be used.

(e) Obtain and evaluate data. Many types of data are required including data on physical and performance characteristics, operational concepts, logistics concepts and relevant historical data. An important part of data evaluation is to identify data limitations or deficiencies and areas of uncertainty.

(f) Identify areas of cost uncertainty. It is important to remember that at this phase in the weapon system's life cycle, uncertainties on all dimensioned planning values are extremely large. It is, therefore, important to define the consequences of all types of uncertainty (cost estimating techniques employed, technical and program) which may have an impact on the cost estimates and to include sensitivity analyses of critical assumptions.

(3) Data Sources

(a) Analogous system cost, design and performance data.

(b) USAF Cost and Planning Factors (AFR 173-10).

(c) Variable factors developed by the ICA team.

(d) AFLC cost estimating relationships.

(e) Competent technical personnel and Air Logistic Center (ALC) equipment specialists.

(f) Cost Information System (CIS) (AFSCM 173-2).

(4) Analysis Results

(a) Information to prepare documentation and briefing charts in the format prescribed by AFR 173-11.

(b) A detailed description of the system's cost sensitive physical characteristics (weight, speed, ranges, etc.).

(c) A description of the characteristics of the system used for parametric analyses or analogy.

(d) Development, procurement and operating and support cost estimates in constant (base year) and current year dollars and a discussion of applicable ground rules and assumptions, estimating procedures, data sources, models and/or Cost Estimating Relationships (CERs), learning curves, uncertainty and risk.

(e) Comparable estimates for all alternatives that are to be presented to the DSARC.

(f) A comparative analysis at the subsystem level of the Independent Cost Analysis versus the program office estimates in constant (base year) and current year dollars.

(g) A feasibility assessment of attaining the design to cost goals that are to be included in the Decision Coordinating Paper.

4-2.5 Development of a Procurement Approach

a. Objectives. The objectives of this analysis are: (1) to establish the overall role of life cycle costing in the development approach and procurement strategy to arrive at design, procurement and other program decisions; and (2) to determine how life cycle cost procurement techniques, such as award fee provisions and warranties, are to be used to motivate the contractors to design and produce cost-effective equipment.

b. Approach

(1) Important Considerations and Inputs

(a) The nature of the equipment and historical experience on similar programs.

(b) Program documentation.

(c) Historical support cost data on similar systems and equipment.

(d) Management guidance, direction and constraints.

(e) Recent Life Cycle Cost procurement experience on other programs.

(2) Steps and Methods

(a) Notify industry early. Industry should be advised of the Government's intent to use life cycle costing as early as possible to obtain maximum benefits from trade-offs that are generally made early in the conceptual phase. From the outset of a program, the contractor's program approach should incorporate the life cycle costing philosophy on early Air Force funded conceptual studies. On major programs these studies are accomplished several years prior to the release of the hardware development program request for proposal (RFP).

(b) Identify and analyze the procurement approach alternatives and select the most compatible procurement concept for all phases of the acquisition program. The extent and duration of competition, the types of contracts, use of incentive or award fee provisions, source selection approach and life cycle cost and design to cost considerations are to be included in the analysis. The life cycle cost procurement strategy must be formulated based on the Government's ability to identify, define and measure the cost sensitive elements that a particular system demonstrates when deployed and the relative importance or magnitude of the various cost categories.

(c) Formulate the rationale for use or non-use of life cycle costing.

(d) Select and describe methods for verifying operating and support costs.

(e) Develop a model for estimating bid and demonstrated operating and support costs. The AFLC Logistics Support Cost (LSC) model (Appendix C, Section I.A) can serve as a basic model, however, it may require tailoring for application to the particular program (cost sensitive elements only).

(f) Determine the logistics support costs to be covered by the model.

(3) Data Sources

(a) Analogous system support cost data.

(b) Experience on past programs.

(4) Analysis Results

(a) Input to proposal activities.

(b) Rationale for the Advanced Procurement Plan (APP).

(c) Proposed life cycle cost provisions for subsequent contracts.

(d) Criteria for identifying life cycle cost/design to cost trade studies.

(e) Identification of cost data and information to be provided to and submitted by the bidders.

(f) Plan for developing a life cycle cost tracking system to more effectively manage the program.

4-2.6 Planning the Use of Life Cycle Cost in the Validation Phase Source Selection

a. Objectives. The objectives of this analysis are: (1) to state the importance of life cycle cost relative to other program objectives; (2) to clearly state what validation phase contractors are to do to reduce life cycle costs; and (3) to develop Request for Proposal (RFP) guidance and source selection criteria that encourage the contractor to evolve low life cycle cost system or equipment design options during the validation phase.

b. Approach

(1) Important Considerations and Inputs

(a) Results of 4-2.5, Development of a Procurement Approach.

(b) Comparable current and historical data.

(2) Steps and Methods

(a) Develop an overall plan to search for life cycle cost reduction opportunities.

(b) Determine how the contractor should present life cycle cost reduction opportunities and supporting information.

(c) Determine how information to be provided by (b) will be evaluated.

(d) Determine the relative importance of reliability and maintainability requirements and goals.

(e) Determine how the contractor should present reliability and maintainability trade-offs and supporting information.

(f) Determine how information provided by (e) will be evaluated.

(g) Determine criteria for source selection, and develop source selection evaluation standards.

(h) Develop special provisions covering life cycle cost and design to cost to be included in the Request for Proposal.

(3) Data Sources

(a) Contractual provisions of analogous acquisition programs.

(b) Analogous system support cost data.

(4) Analysis Results

(a) Source selection criteria and standards.

(b) Special life cycle cost and design to cost provisions to be included in the Request for Proposal.

(c) Detailed source selection plans and back up information.

4-3 Validation Phase Analysis Tasks

4-3.1 Validation Phase Life Cycle Cost Design Trade Studies

a. Objectives. The primary objectives of this analysis are: (1) to assure that life cycle costs are logically and consistently considered in continuing equipment and support system design iterations; (2) to promote innovation among competing vendors to offer lower ownership cost designs; and (3) to continually assess the life cycle cost implication of requirements. Design trade studies accomplished during this period are especially important because there is generally competition to increase the motivation for innovation and less pressure to arrive at a final design than during the subsequent full scale development phase. In addition, prototype hardware may be built and tested, providing useful life cycle cost design trade study information.

b. Approach

(1) Important Considerations and Inputs

(a) System reliability and maintainability requirements and goals.

(b) The nature and relative importance of resource constraints (such as, desired Initial Operational Capability (IOC) date, design to cost goals).

(c) Minimum performance goals and objectives.

(d) Design alternatives.

(2) Steps and Methods

(a) Identify critical cost sensitive areas. All programs and products differ. Most are complex and could involve an almost infinite number of design trade studies. Therefore, it is essential to identify the most critical areas for analysis. This can be done by examining historical data on similar systems and equipments, and in every other way possible gaining an understanding of the life cycle cost implications of design differences. Of particular importance are design alternatives which significantly affect reliability, maintainability and acquisition costs. Look into past problem areas such as stress corrosion, fatigue damage, overheating and complexity. Make use of any available test data to search out potential high cost problem areas.

(b) Search for low life cycle cost design alternatives. For the design areas selected above, appropriate design specialists must search out and describe lower life cycle cost design alternatives. Possible approaches to such design alternatives include:

1. Limited performance improvement objectives.

2. Elimination of non-mission essential functions.

3. Design simplicity.

4. Greater use of standard or commercial products.

5. Greater use of design inheritance.

6. Design to facilitate multiple source competition.

7. Compatibility with more efficient test and fault finding procedures.

8. Improved accessibility.

9. Use of standard support and test equipment (SE).

10. Reduced manpower skill requirements.

(c) Assess the life cycle cost implications of design alternatives. It is never easy to obtain or develop mathematical formulae relating design parameter values to life cycle costs. However, Maintenance Engineering Analysis (MEA), Failure Mode and Effects Analysis (FMEA) and life cycle cost models can provide design guidance. At this stage in the system design, attention should be placed on resolving life cycle cost differences between use of existing or new equipment, avionics architecture, cost sensitive performance parameters, etc.

(d) Document the cost-design trade study results. Considerable judgement may be needed to adapt available data and methods to meet cost-design trade study analysis needs. Those conducting the studies seldom have the final authority for significant design-trade decisions; therefore, it is essential that all analysis methods and assumptions be documented. Of particular importance is how proposed equipment reliability and maintainability parameters were obtained for the design options assessed. Wherever possible, a logical relationship or basis for extrapolation should always be shown between proposed equipment reliability and maintainability parameter values and historical field experience data on related equipment. Wherever quantitative life cycle cost differences exist, they should be supported by qualitative arguments.

(3) Data Sources

(a) Historical data. AFSC/AFLC Pamphlet 400-11 describes the sources of historical reliability and maintainability data. Use of this historical data is an important supplement to assessments of reliability and maintainability characteristics obtained from reliability and maintainability testing programs.

(b) Government and industry design, maintenance and logistic support experts. Valuable information from past problems and successes does not always find its way into available data files. This information should be recovered from those having this experience.

(c) Other program trade studies. A review of other program trade study activities can provide considerable insight into both how to design a system and how to conduct trade studies. This source of assistance and information involves approaching program offices directly to seek help.

(d) Test results. While most reliability and maintainability test programs are too short to make good reliability and maintainability predictions of equipment field performance, they can be the source of valuable information to alert one to pending reliability and maintainability problem areas.

(4) Analysis Results

(a) An economic assessment of feasible performance requirements.

(b) A re-examination of performance goals in terms of life cycle cost.

(c) A basis for evaluating major performance goals and design alternatives, which includes consideration of life cycle costs.

(d) Design guidance for achieving a defined level of performance requirements.

(5) Contractor Activities. Contractors can play an invaluable role in the validation phase life cycle cost design trade studies. They must be given adequate guidance with respect to program objectives and importance of life cycle costs. This includes guidance concerning USAF plans to use and support the system and all major performance parameters and cost and schedule objectives. Contractor life cycle cost design trade studies for major systems should be mandatory.

4-3.2 Cost of Ownership Refinement

a. Objective. The objective of this analysis is to refine the cost of ownership estimate to reflect validation phase activity generated system design data.

b. Approach

(1) Important Considerations and Inputs

(a) Results of 4-2.3, Cost of Ownership Assessments.

(b) Updated program documentation.

(c) Cost Estimating Procedures (AFSCM 173-1).

(d) Test and Evaluation Information.

(e) Test and Evaluation Guidance (AFLCM 800-1, Chapter 24).

(2) Steps and Methods

(a) Understand the nature of any differences in program characteristics from the previous cost of ownership assessment.

(b) Establish cost estimating relationships for individual cost categories, such as depot maintenance, which are sensitive to specific hardware characteristics.

(c) Augment the Cost Analysis Cost Estimating (CACE) model with a component-level model, such as the AFLC Logistics Support Cost Model, using test data to estimate reliability and maintainability characteristics of individual components. Where appropriate, initial and replenishment spares costs should be refined through the buildup of anticipated spares requirements for individual components, and base level maintenance requirements refined utilizing the maintenance manpower requirements model. These models are described in Appendix C.

(3) Data Sources

(a) Analogous system cost, design and performance data.

(b) USAF Cost and Planning Factors (AFR 173-10).

(c) Prototype test data and information.

(4) Analysis Results

(a) A description of the baseline used for the cost of ownership estimate including the operational scenario and maintenance concept.

(b) A statement of confidence in the values presented and design sensitive techniques used to estimate various costs.

(c) Cost of ownership estimates to support various program decisions and program reviews to: (1) track and assess the impact of changes in requirements, design or system capability; (2) provide a basis for determining if potential costs are within antici-

pated funding levels; (3) assist in determining a proper balance between cost, schedule and performance; and (4) provide a basis for cost trade-off analyses.

(d) A basis for the cost of ownership assessment to be included in the Decision Coordinating Paper.

4-3.3 Preparation of an Independent Cost Analysis (ICA) for DSARC II

a. Objective. The objective of this Independent Cost Analysis is to support the full scale development decision process by providing: (1) an independent estimate of acquisition and ownership cost estimates of the latest approved program and all alternatives that will be presented to the DSARC; (2) a comparison to the previous Independent Cost Analysis with supporting variance analysis; (3) a comparison to previous program office estimates including the Cost of Ownership assessment with supporting variance analysis; and (4) an assessment of the validity of the design to cost goals.

b. Approach

(1) Important Considerations and Inputs

(a) Hq USAF criteria provided in the tasking order.

(b) Previous system/program Independent Cost Analysis.

(c) Updated program documentation.

(d) Historical data.

(e) Program office and contractor reports on costs to date.

(f) Cost Estimating Procedures (AFSCM 173-1).

(2) Steps and Methods

(a) Understand the nature and unique characteristics of the system/equipment. Particular attention must be given to those facets of the system that impact life cycle cost. Of particular importance are the operational concept, maintenance concept, physical and performance characteristics, organizational and training concepts, implementation and installation concepts, technology, test programs, production quantities and schedules.

(b) Update background information. Determine and document events that occurred during the validation phase that led up to the decision to seek full scale development approval, and note all management guidance and direction received since any previous Independent Cost Analysis.

(c) Update ground rules and assumptions. Any changes from the previous Independent Cost Analysis should be noted. Again, the program manager should review all ground rules and assumptions.

(d) Select the estimating methods. The use of parametric costing techniques should again be used whenever appropriate. Information available during this period is more detailed than in concept formulation. For example, some system performance estimates, some test data, some specific design characteristics, some limited detail design and preliminary make or buy lists are usually available. With this kind of information, a portion of the costs can be checked and validated through detailed estimates.

(e) Obtain and evaluate data. Again, many types of data are required with emphasis on updating previous data in order to refine any factors that were developed by parametrics or analogoús comparisons. Data should also be obtained to validate or check estimates from information discussed in (d). The time constraint will be the critical element in determining how much data can be obtained. The most important part of data evaluation is the identification of data limitations.

(f) Identify areas of cost uncertainty. Although significantly more information is available, many uncertainties remain. It is, therefore, important to define the consequences of all types of uncertainty (cost estimating, technical and program) which may have an impact on the cost estimates. A sensitivity analysis on all critical assumptions should be included in this analysis.

(3) Data Sources

(a) Analogous systems.

(b) USAF Cost and Planning Factors (AFR 173-10).

(c) Variable factors developed by the Independent Cost Analysis team and previous Independent Cost Analysis data.

(d) Experts, highly competent technical personnel, Air Logistic Center (ALC) equipment specialists, operating command maintenance specialists and Air Training Command (ATC) training specialists.

(e) Prototype data and information.

(f) Test data.

(g) Cost Information System (CIS) (AFSCM 173-2).

(4) Analysis Results

(a) Information to prepare documentation and briefing charts in the format prescribed by AFR 173-11.

(b) A detailed description of the system's cost sensitive physical characteristics (weight, speed, ranges, etc.).

(c) A description of the characteristics of the systems used for parametric analyses or analogy.

(d) Development, procurement and operating and support cost estimates in constant (base year) and current year dollars and a discussion of applicable ground rules and assumptions, estimating procedures, data sources, models and/or Cost Estimating Relationships (CERs), learning curves, uncertainty and risk.

(e) A comparable cost estimate for all alternatives that are required to be presented to the DSARC.

(f) A comparative analysis at the subsystem level of the Independent Cost Analysis versus the program office estimates in constant (base year) and current dollars.

(g) A comparative analysis of the current Independent Cost Analysis to the previous Independent Cost Analysis.

(h) A summary assessment of the feasibility of attaining design to cost goals that are to be included in the Decision Coordinating Paper.

4-3.4 Refinement of the Procurement Approach

a. Objectives. The objectives of this analysis are to update and expand the development procurement plans initiated in the conceptual phase and develop life cycle cost related contractual provisions for the full scale development contract.

b. Approach

(1) Important Considerations and Inputs

(a) Historical events.

(b) Program documentation.

(c) Management guidance, direction and constraints.

(d) Development Test and Evaluation (DT&E) and Initial Operational Test and Evaluation (IOT&E) results.

(e) Contractors' desires and motivational efforts (such as company growth, prestige, opportunities for follow-on business, utilization of available skills and open capacity and profit).

(2) Steps and Methods

(a) Review the procurement approach alternatives.

(b) Review all information available from the validation program.

(c) Determine the extent and duration of competition based on the results of (a) and (b).

(d) Determine the Government's ability to identify, define and measure cost sensitive elements of the particular system.

(e) Determine the relative importance or magnitude of the various cost categories.

(f) Determine whether or not to include models in the Request for Proposal and what parameters to specify based on the results of (d) and (e). Bidders should be required to submit supporting rationale for these parameters. Standardized bid formats utilizing a detailed work breakdown structure, provided in the Request for Proposal, can aid in comparing bidders' estimates and assessing differences in bidders' proposals.

(g) Identify what general trade-offs are important using the results of (e) as one source of information.

(h) Determine if incentive provisions are appropriate. The objective of an incentive provision is to motivate the contractor to achieve better performance and control life cycle costs. An incentive arrangement can have a positive and negative feature.

(i) Design the incentive provision to relate the amount of compensation to the value received. This can be accomplished by determining a dollar value for various levels of performance characteristics and quantifying what is necessary to motivate the contractor considering other contractor's desires besides profit.

(j) Determine whether or not to include guarantees on logistics values (such as a reliability improvement warranty with an MTBF guarantee), and when and how such values should be tested and evaluated. Develop a failure definition with the assistance of engineering, procurement and legal personnel.

(k) Determine the design to cost goals for the subsystems in context with overall program design to cost goals, trade studies provisions and life cycle cost estimates. Other design to cost goals must be clearly defined in the Request for Proposal. The definition should include types of costs and items to be included in the design to cost goal. The design to cost clauses should set forth the supporting rationale including the anticipated production quantities, production rates, cost/quantity relationships, duration of the program and escalation factors to be used. The Request for Proposal should specify that the contractor will be required (1) to document the trade-offs made to meet acceptable performance within the design to cost goal; (2) to demonstrate the effects of these trade-offs on achieving the design to cost goal; and (3) to assess the impact of these trade-offs on Life Cycle Cost, especially operating and support costs. The manner in which the contractor intends to implement the design to cost requirements should also be covered in the Request for Proposal. The bidders' proposals should cover management review and control procedures and feedback mechanisms between design and production groups.

(l) Prepare a special provision to be included in the contract awarded outlining the contractor's understanding of logistics support cost guarantees and related contractual commitments.

(3) Data Sources

(a) Validation phase results.

(b) Lessons learned from previous programs.

(c) Historical data.

(4) Analysis Results

(a) Updated procurement plan.

(b) Provisions to be included in the Request for Proposal (RFP).

(c) Incentive and award fee provisions.

(d) Criteria for identifying life cycle cost/design to cost trade studies.

(e) Identification of cost data and information to be submitted by the contractor(s).

(f) A corporate commitment provision.

4-3.5 Life Cycle Cost Verification Test Plan

a. Objective. The objective of this analysis is to prepare the post-award test plan required to assess the contractor's success in achieving his life cycle cost commitment.

b. Approach

(1) Important Considerations and Inputs

(a) Results of 4-3.4, Refinement of the Procurement Approach.

(b) Nature of the equipment and proposed maintenance concept.

(c) Organic or contract maintenance.

(d) Test and Evaluation Plans.

(2) Steps and Methods

(a) Determine the test sample size, method of sample selection (e.g., proportional to production rate), means of measuring usage (e.g., flying hours or operating hours) and source of measurement (e.g., AFM 65-110 reporting or elapsed time indicators).

(b) Determine how reliability maturation will be considered in test results if appropriate for selected equipment.

(c) Determine the appropriate length of the test and provisions for ensuring sufficient test hours.

(d) Select representative test vehicles, and make provisions for selection of representative number of each type of test vehicle and expected usage.

(e) Select representative test sites.

(f) Determine who will accomplish the test (e.g., Air Force Maintenance personnel), how they will be selected and trained and whether or not they will be certified by the contractor.

(g) Establish procedures for the maintenance, installation and removal of test samples.

(h) Develop and clearly define a definition of test failures including exceptions for "acts of God."

(i) Develop procedures for failure verification.

(j) Specify the frequency of review meetings to be attended by the contractor and specified representatives from the Government to review test procedures and results.

(k) Specify forms and procedures for data collection and reporting.

(l) Explicitly define what constitutes completion of the test.

(m) Define the formulae for verification calculations.

(3) Data Sources

(a) Lessons learned from previous programs.

(b) Test and evaluation documentation.

(4) Analysis Results

(a) A verification test plan to be included in the Request for Proposal and subsequent contract.

(b) Preliminary verification test procedures.

4-3.6 Planning for and Using Life Cycle Cost in the Full Scale Development (FSD) Source Selection

a. Objective. The objective of this analysis is to provide all bidders for full scale development with: (1) clear guidance on the importance of life cycle costs and continued consideration thereof; (2) data and guidance on how to estimate and substantiate the life cycle costs of the designs being proposed; (3) an understanding of the role of life cycle cost estimates and bidders' plans for further life cycle cost reduction actions in the source selection evaluation; and (4) a full and clear understanding of the planned use of any submitted life cycle cost data with respect to incentive, warranty or other contract provisions.

b. Approach

(1) Important Considerations and Inputs

(a) Results of 4-3.4, Refinement of the Procurement Approach.

(b) Source selection experience on other programs.

(2) Steps and Methods

(a) Structure the results of 4-3.4 into contractual provisions.

(b) Determine source selection criteria and means and techniques for source selection evaluation.

(c) Perform sensitivity studies to determine which parameters contribute most significantly to life cycle cost.

(d) Arrange for independent reliability assessments in order to assess the reasonableness of the contractors' proposed MTBF and other cost driving parameters.

(3) Data Sources

(a) Contractual provisions of analogous acquisition programs.

(b) Analogous system support cost data.

(4) Analysis Results

(a) Source selection criteria.

(b) Provision to be included in the Request for Proposal.

(c) Detailed source selection plans and back up information.

4-4 Full Scale Development Analysis Tasks

4-4.1 Detailed System and Support Life Cycle Cost Design Trade Studies

a. Objectives. The primary objectives of this analysis are: to assure (1) that detail design decisions, many of which significantly affect system reliability and maintainability, are arrived at only after proper consideration of life cycle costs; (2) that important life cycle cost design trade study issues surfaced during the full scale development source selection are properly addressed and the results reflected into the production design; and (3) that, as long as system and support design activities continue, life cycle costs are considered in arriving at design decisions.

b. Approach

(1) Important Considerations and Inputs

(a) System and subsystem reliability and maintainability requirements and goals.

(b) Design to cost goals, life cycle cost estimates and desired Initial Operational Capability (IOC) date.

(c) Performance goals and objectives.

(d) Reliability and maintainability demonstration and test results.

(e) Detailed design drawings and other design information.

(f) Previous and related trade studies.

(g) Producibility studies.

(h) Historical field support cost data on related system and equipment.

(2) Steps and Methods. The general procedures for these trade studies are the same as those described in 4-3.1, Validation Phase Life Cycle Cost Design Trade Studies. During this phase of the program more design details are known and are subject to analysis. Trade studies relate closely to system and equipment reliability and maintainability. Therefore, design factors affecting reliability and maintainability should be assessed to estimate the life cycle cost differences among alternatives. These analyses should be consistent with the system support plan. Specific issues in addition to those listed in 4-3.1 include:

(a) Use of higher reliability parts.

(b) Optimum repair level analysis.

(c) Scheduled maintenance requirements.

(d) Reliability and maintainability testing requirements and decision criteria.

(3) Data Sources

(a) Reliability and maintainability data sources identified in AFLC/AFSC Pamphlet 400-11.

(b) Test results.

(c) Related system and equipment trade studies.

(d) Experts from government and industry.

(4) Analysis Results

(a) Design guidance for achieving performance requirements.

(b) Demonstrated reliability and maintainability requirements.

(c) A basis for evaluating design alternatives.

(d) A basis for monitoring and assessing the developer's design and support decisions, including engineering change proposals.

(e) Optimum repair level decisions.

(f) An optimum maintenance and support plan.

(5) Contractor's Activities. The contractor must routinely employ a suitable life cycle cost model or family of models, in an interactive manner between his design and engineering organizations and his ILS, cost and pricing organizations. All feasible trade-off alternatives should be analyzed, evaluated and approved by these organizations. The design and support decisions should be tracked and validated by the program office.

4-4.2 Cost of Ownership Refinement

a. Objective. The objective of this analysis is to refine the cost of ownership estimate to reflect full scale development phase activity generated system design data.

b. Approach

(1) Important Considerations and Inputs

(a) Results of 4-3.2, Cost of Ownership Refinement.

(b) Updated program documentation.

(c) Cost Estimating Procedures (AFSCM 173-1).

(d) Test and Evaluation Data.

(e) Test and Evaluation Guidance (AFLCM 800-1, Chapter 24).

(2) Steps and Methods

(a) Understand the nature of any differences in program characteristics from previous cost of ownership assessments.

(b) Refine cost estimating relationships for individual cost categories, such as depot maintenance, which are sensitive to specific hardware characteristics.

(c) Augment the Cost Analysis Cost Estimating (CACE) model with a component level model, such as the AFLC Logistics Support Cost Model, using DT&E and IOT&E data to estimate reliability and maintainability characteristics of individual components. Estimates should be revised using the results of maintenance engineering analyses and repair level analyses.

(d) Estimates should also be modified based on observed test results. Data collected solely from a program's test events is insufficient to assess all cost categories; however, variables measured during the supportability test should be updated or used. These normally will include frequency of maintenance actions, maintenance task times and Not Reparable This Station (NRTS) rates. From these variables, refinement of manpower requirements, shipping costs, support equipment requirements and depot repair costs can be addressed. Caution should be exercised in revising variables based on limited test results.

(e) A detailed analysis should be performed in the event that the revised cost of ownership estimate reflects a significant potential increase in operating and support cost. The analysis should identify the system or equipment contributing the most to the difference, the support resource areas impacted and the probable cause for variations.

(3) Data Sources

(a) Analogous system cost, design and performance data.

(b) USAF Cost and Planning Factors (AFR 173-10).

(c) DT&E and IOT&E data.

(d) Maintenance engineering analysis and repair level analysis data.

(4) Analysis Results

(a) A description of the baseline used for the cost of ownership estimate including the operational scenario and maintenance concept.

(b) A statement of confidence in the values presented and design sensitive techniques used to estimate various costs.

(c) Cost of ownership estimates to support various program decisions and program reviews to: (1) track and assess the impact of changes in requirements, design or system capabilities; (2) provide a basis for determining if potential costs are within anticipated funding levels; (3) assist in determining a proper balance between cost, schedule and performance; and (4) provide a basis for cost trade-off analyses.

(d) A basis for the Cost of Ownership Assessment to be included in the Decision Coordinating Paper.

4-4.3 Preparation of Independent Cost Analysis for DSARC III

a. Objective. The objective of this Independent Cost Analysis (ICA) is to support the production decision process by providing: (1) an independent estimate of acquisition and ownership cost estimates of the latest approved program and all alternatives that will be presented to the DSARC; (2) a comparison to the previous Independent Cost Analysis with supporting variance analysis; (3) a comparison to program office estimates, including cost of ownership assessment, with supporting variance analyses; and (4) an assessment of the validity of the design to cost goals.

b. Approach

(1) Important Considerations and Inputs

(a) Hq USAF criteria provided in the tasking order.

(b) Previous system/program Independent Cost Analyses.

(c) Program office system design and performance estimates.

(d) Updated program documentation.

(e) Program office and contractor reports on costs to date.

(f) Test results.

(g) Cost Estimating Procedures (AFSCM 173-1).

(2) Steps and Methods

(a) Understand any changes from the previous description of the system.

(b) Update background information. Determine and document events that occurred during full scale development that led up to the decision to seek production approval, and note all management guidance and direction received since the previous Independent Cost Analysis.

(c) Update ground rules and assumptions. Any changes from the previous Independent Cost Analysis should be noted. The program manager should review all ground rules and assumptions.

(d) Select the estimating methods. Parametric costing techniques should be used whenever appropriate. Information available during this period is considerably more detailed, thus making it possible to check and validate many elements of cost through detailed estimates.

(e) Obtain and evaluate data. Considerable data is available from DT&E and IOT&E. The most important part of data evaluation is the identification of data limitations. Time will be the major constraint on how much data can be obtained and evaluated.

(f) Identify areas of cost uncertainty. Although significantly more information is available, uncertainties, particularly in the operating and support cost area, remain. It is, therefore, important to define the consequences of all types of uncertainty (cost estimating, technical and program) which may have an impact on the cost estimates. A sensitivity analysis of all critical assumptions should be included in the analysis.

(3) Data Sources

(a) Analogous systems.

(b) USAF Planning Factors (AFR 173-10).

(c) Previous Independent Cost Analysis data.

(d) Program office product and program descriptions.

(e) DT&E, IOT&E and other test data.

(f) AFLC equipment and maintenance specialists, operating command maintenance personnel, ATC training specialists, engineering and technical personnel and other appropriate specialists.

(g) Cost Information System (CIS) (AFSCM 173-2).

(4) Analysis Results

(a) Information to prepare documentation and briefing charts in the format prescribed by AFR 173-11.

(b) A detailed description of the system's cost sensitive physical characteristics (weight, speed, range, etc.) and identification of any differences from the previous Independent Cost Analyses.

(c) A description of the characteristics of the systems used for parametric analyses or analogy.

(d) Development, procurement and operating and support cost estimates in constant (base year) and current year dollars and a discussion of applicable ground rules and assumptions, estimating procedures, data sources, models and/or Cost Estimating Relationships, learning curves, uncertainty and risk.

(e) An estimate for all alternatives that are to be presented to the DSARC.

(f) A comparative analysis at the subsystem level of the Independent Cost Analysis versus the program office estimates in constant (base year) and current year dollars.

(g) A comparative analysis of the current Independent Cost Analysis to the previous Independent Cost Analysis.

(h) A feasibility assessment of attaining design to cost goals that are included in the updated Decision Coordinating Paper.

4-4.4 Planning the Use of Life Cycle Cost in the Production Contract Source Selection and Negotiations

a. Objective. Where life cycle cost provisions or options for such provisions have not been finalized, the objective of this analysis is to provide all production contract bidders with: (1) clear guidance on the importance of life cycle costs and continued consideration thereof; (2) data and guidance on how to estimate and substantiate the life cycle costs of the designs being proposed; (3) an understanding of the role of life cycle cost estimates and bidders' plans for further life cycle cost reduction actions in source selection evaluation; and (4) a full and clear understanding of the planned use of any submitted life cycle cost data with respect to incentive, warranty or other contract provisions. The analysis approach is essentially that described in 4-3.6, Planning the Use of Life Cycle Cost in the Full Scale Development Source Selection, modified as appropriate for the production phase. Where the full scale development contractor in essence automatically becomes the production contractor, the objective of this analysis is to technically and economically assess the system or equipment to make all warranty, guarantee option and other contract provision decisions so as to reduce life cycle costs.

b. Approach

(1) Important Considerations and Inputs

(a) Historical data.

(b) Labor costs and contractor profit.

(2) Steps and Methods

(a) Develop a range of "should costs" for the option provisions, such as the reliability improvement warranty and reliability improvement warranty with MTBF guarantee options.

(b) Develop plans for assessing test data.

(c) Perform sensitivity analyses to evaluate key life cycle cost factors for various equipments being considered.

(d) Determine how uncertainties associated with the verification test measurement methods are to be handled.

(e) Establish and specify the criteria for award fee distribution, if applicable.

(f) Establish communications with the contractors to ensure understanding of the provisions and strategy for use.

(g) Define exactly how warranty and guarantee option responses will be used during source selection and contract award, including how much bearing these bid prices will have on the selection of the contractors' proposals.

(h) Establish detailed plan of data collection, and discuss it with all bidders if a verification test

(3) Data Sources

(a) Historical data.

(b) Cost factors for pricing.

(4) Analysis Results

(a) A basis for stating and evaluating warranty and guarantee options.

(b) A plan for evaluating the proposal responses in source selection.

4-5 Production Phase Analysis Tasks

4-5.1 Engineering Change Proposal (ECP) Reviews

a. Objective. The objective of this analysis is to provide estimates of life cycle cost differences and assess the cost implications of proposed changes so that the decision to accept or reject the Engineering Change Proposal can be made with the knowledge of the life cycle cost implications.

b. Approach

(1) Important Considerations and Inputs

(a) Baseline configuration.

(b) Description and major implications of change proposal.

(c) Life cycle cost model.

(d) Contractual provision covering change proposals.

(2) Steps and Methods

(a) Compute the life cycle cost for the original (base line) configuration.

(b) Compute the life cycle cost for the new (proposed) configuration.

(c) Assess the reasonableness and validity of the change and cost difference.

(d) Identify areas of uncertainty and perform appropriate sensitivity analysis.

(e) Make a cost benefit assessment, use economic analysis if acquisition and support costs are to be traded off.

(3) Data Sources

(a) Engineering Change Proposal - contractor may be required to utilize a prescribed format and life cycle cost model.

(b) Technical and engineering personnel assessments.

(c) Design and cost data from comparable systems.

(4) Analysis Results

(a) Cost differences in terms of both acquisition and operating and support costs.

(b) A cost-benefit analysis of the change proposal.

(c) Other relevant factors including areas of uncertainty on the accept-reject decision not included in the cost benefit analysis.

4-5.2 Development of Warranty/Guarantee Option Selection Decision Guidance

a. Objective. The objective of this analysis is to provide an economically sound basis for making timely warranty and guarantee option selection decisions if such provisions have been incorporated into the contract.

b. Approach

(1) Important Considerations and Inputs

(a) Results of 4-4.4, Planning the Use of Life Cycle Cost in the Production Contract Source Selection and Negotiations.

(b) Contract option provisions.

(c) Nature of equipment and its association with other equipments, equipment failure modes, repair level analyses, etc.

(d) Normal organic maintenance procedures for such equipment.

(e) Recent warranty and guarantee experience on similar equipment.

(2) Steps and Methods

(a) Clearly define option alternatives being assessed and associated decision required.

(b) Identify and list costs which will vary as a function of alternative selection decisions. Costs to be considered include in-house Air Force operating and support costs, option costs, contract price and fee adjustments.

(c) Develop a model(s) to relate all variable costs identified to MTBF or other primary factors affecting life cycle cost for each alternative.

(d) Estimate variations in MTBF or other primary factors affecting variable costs for each alternative.

(e) Estimate the life cycle cost differences to the Government for each alternative using information developed.

(f) Based on the data derived in (e), uncertainty in the estimated costs, MTBF and other non-quantifiable considerations, rank the options, and provide supporting rationale.

(3) Data Sources

(a) All test results relating to equipment reliability, maintainability and supportability characteristics.

(b) Organic support cost factors and data.

(c) Contractor warranty and guarantee option costs.

(4) Analysis Results

(a) Life cycle cost differences for the various options.

(b) Recommended option selection actions.

(c) Justification for recommended option selection actions.

4-5.3 Life Cycle Cost Verification Testing

a. Objective. The objective of this analysis is to complete detailed planning for the life cycle cost verification test program.

b. Approach

(1) Important Considerations and Inputs

(a) Results of 4-3.5, Life Cycle Cost Verification Test Plan.

(b) Other test results.

(2) Steps and Methods

(a) Review the procedures and activities contained in the Life Cycle Cost Verification Test Plan with the contractor and using command.

(b) Finalize all procedural details.

(c) Select the test cadre.

(d) Ensure availability of training equipment and training documentation.

(e) Ensure availability of support equipment to the test program.

(f) Establish base and depot level repair facilities.

(g) Finalize reporting procedures.

(3) Data Sources

(a) Test plans.

(b) Other test results.

(4) Analysis Results

(a) A clear understanding of the Government's and contractor's obligations and responsibilities during the test program.

(b) The capability to closely monitor the test program.

Chapter 5

Methods and Terms Used In Life Cycle Cost Analysis

5-1 Objective

This chapter explains the methods and terms mentioned in Chapter 4 and other methods and terms which should assist analysts in developing an LCC analysis approach for a specific program application. A generalized LCC analysis approach is schematically shown in Figure 5-1 to help readers understand the overall LCC analysis process, and to be used as a baseline LCC analysis approach which can be tailored to meet specific program LCC analysis requirements. The methods discussed in Section 5-3 are categorized primarily by their role relative to the decision making process, i.e., cost estimate preparation methods, engineering and other analysis methods, and analysis methods for management decisions.

5-2 Developing New LCC Analysis Approaches

The tasks described in Chapter 4 are only representative of the many LCC analysis approaches which may be applied to solve a variety of LCC related problems, any of which may be approached in a number of ways. This section and Figure 5-1 have been included to briefly present a more general LCC analysis approach. Specific LCC analyses must usually be tailored, which means that methods must be selected and adapted to the individual program problems or questions. Figure 5-1 shows one way the individual analysis methods discussed in this chapter can be integrated into an overall LCC analysis approach. The overall message contained in this figure is that LCC analysis consists of various analyses and other activities, is a basic tool to be used in evaluating resource requirements and is employed in conjunction with other considerations in determining cost effectiveness. Life cycle cost estimates introduce the economic information necessary for the comparison of various system or equipment design and support alternatives, and are required for the assessment of risks and uncertainties in the decision making process. The following section includes a description of the methods highlighted in this general LCC analysis approach.

5-3 Life Cycle Cost Analysis Methods and Terms

5-3.1 Introduction. Since almost every program decision affects life cycle costs, life cycle cost analysis may involve use of a broad spectrum of planning, engineering, management and financial analysis methods. The role and relative importance of any one of these methods depends on the overall objectives of the specific LCC analysis task. The nature and role of these methods, many of which were mentioned in Chapter 4, are described

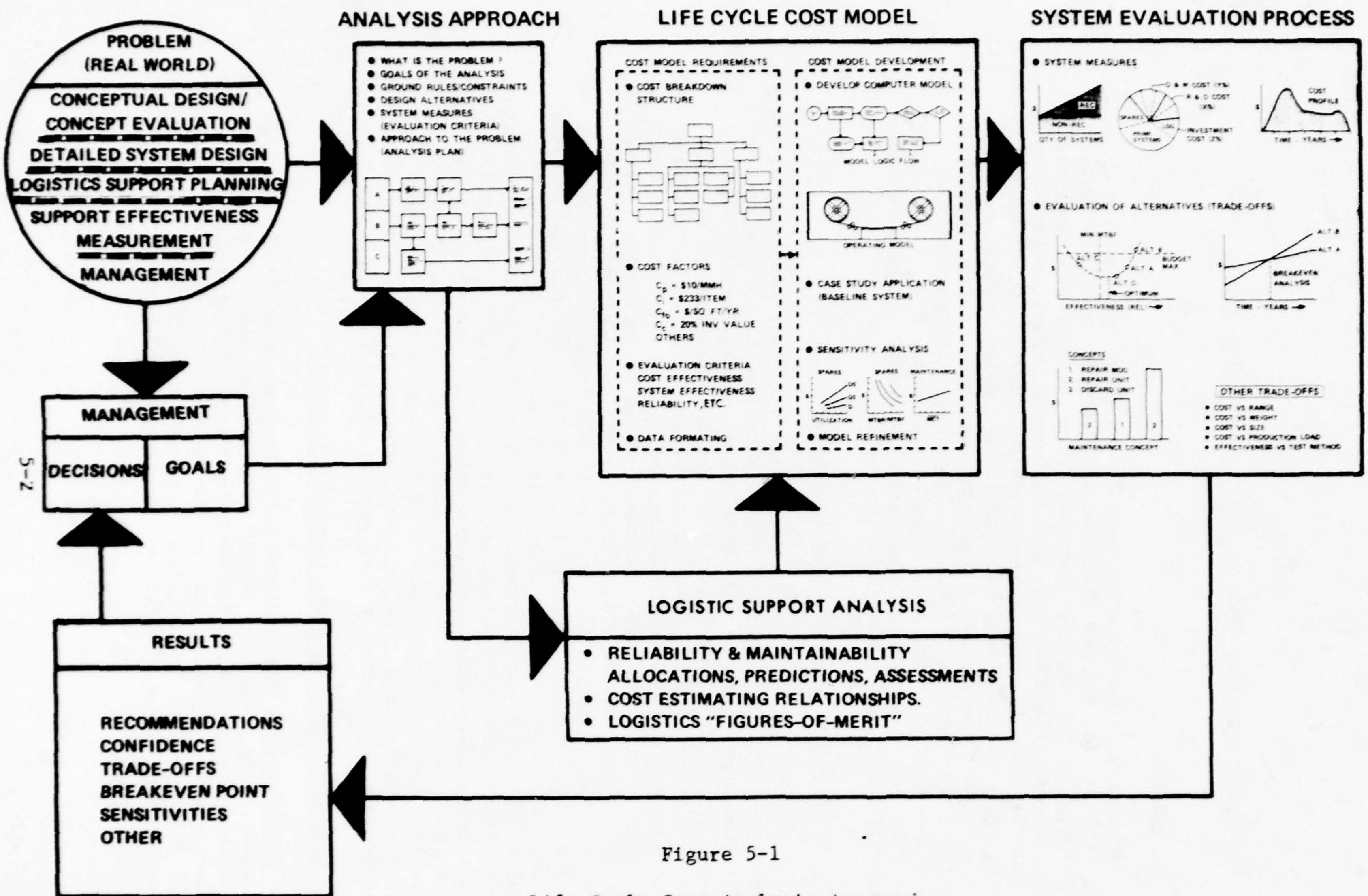


Figure 5-1

Life Cycle Cost Analysis Approach

Source: AFP 800-7

individually in Section 5-3.2, 5-3.3 and 5-3.4. They have been broken into three categories: cost estimate preparation related methods (5-3.3), engineering and other analysis methods (5-3.4) and analysis methods for management decisions (5-3.5). Normally analysis methods for management decisions use the results of cost estimating and engineering analysis to derive a logical basis for decision by examining the likelihood and consequences of all possible outcomes. Section 5-3.6 defines terms which should be understood to effectively develop appropriate analysis approaches for new LCC analysis tasks.

5-3.2 Cost Estimate Preparation Related Methods

a. Cost Breakdown Structure. Cost categories should be compatible with the work breakdown structure (WBS) (Military Standard 881A) and cost reporting requirements. The program portion of this structure summarizes cost data from a discrete defense material item into a DOD program element or an aggregation of elements. Cost categories must be identified in such a manner as to reflect key activity areas plus major elements of support which are considered to have a significant affect on total system life cycle costs. Established cost categories must be sensitive to alternate system design configurations, changes in production quantities and various system logistics support concepts.

Each level of the program/work breakdown structure can be depicted as shown in Figure 5-2, which shows the interface and compatibility of the program structure and the work breakdown structure. These combined structures are organized arrays identifying hardware, software and services produced or performed during the life of a defense material item. They are groups of similar items composed of varying levels of information, each of which is a more detailed breakdown of the preceding. While it is recognized that the definable level of cost breakdown structure detail for each analysis will differ, all costs must be included or specifically identified as excluded costs. In line with established cost categories for a given program specific input cost factors must be defined. Many input factors for determining R&D and investment costs are derived directly from the contractor's internal company engineering and manufacturing cost reporting procedures. Input factors required for the determination of recurring (operations and maintenance) costs must be defined by both the government and the contractor.

For any specific program, a wide range of life cycle cost elements may be included. The elements may include such diverse things as feasibility studies, design and development, production and test, installation and checkout, personnel and training, spare/repair parts, support and test equipment, item entry and inventory management, fuel consumption, maintenance and scrap value, only to name a few. An example of a cost breakdown structure is shown in Figure 5-3.

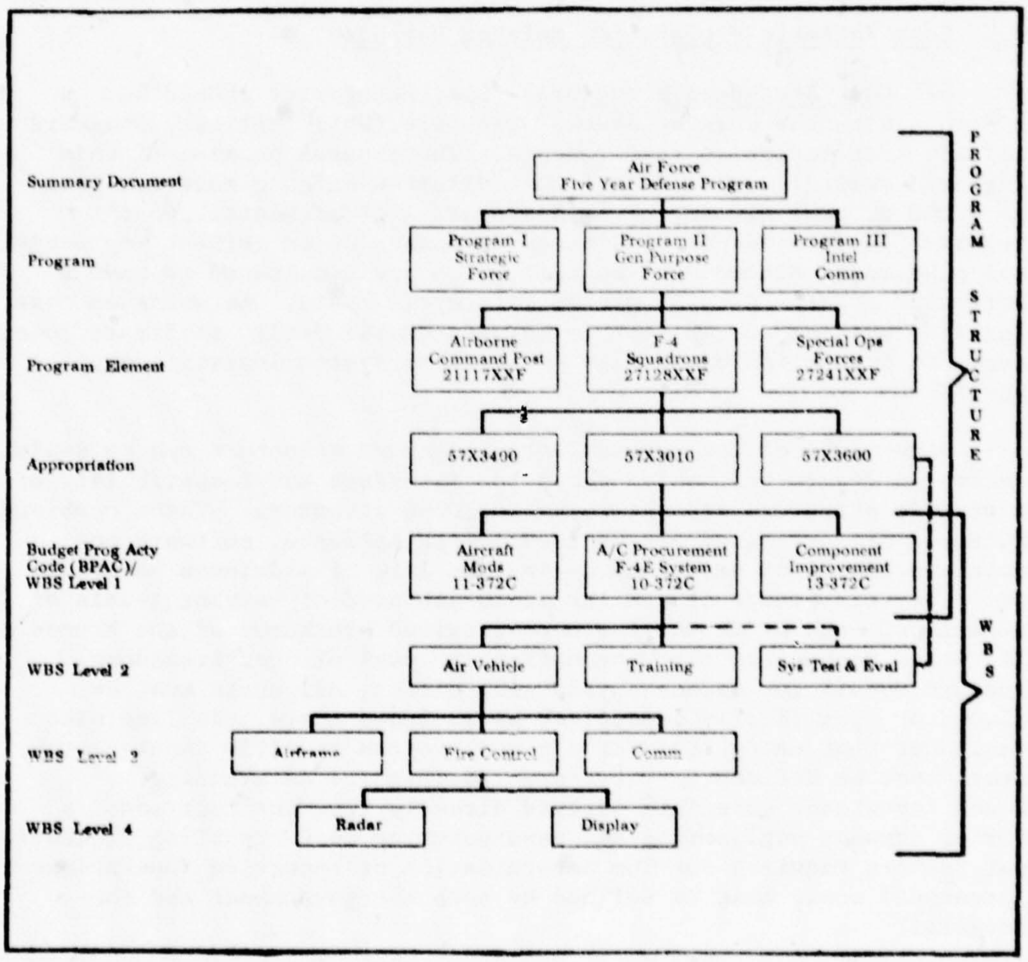
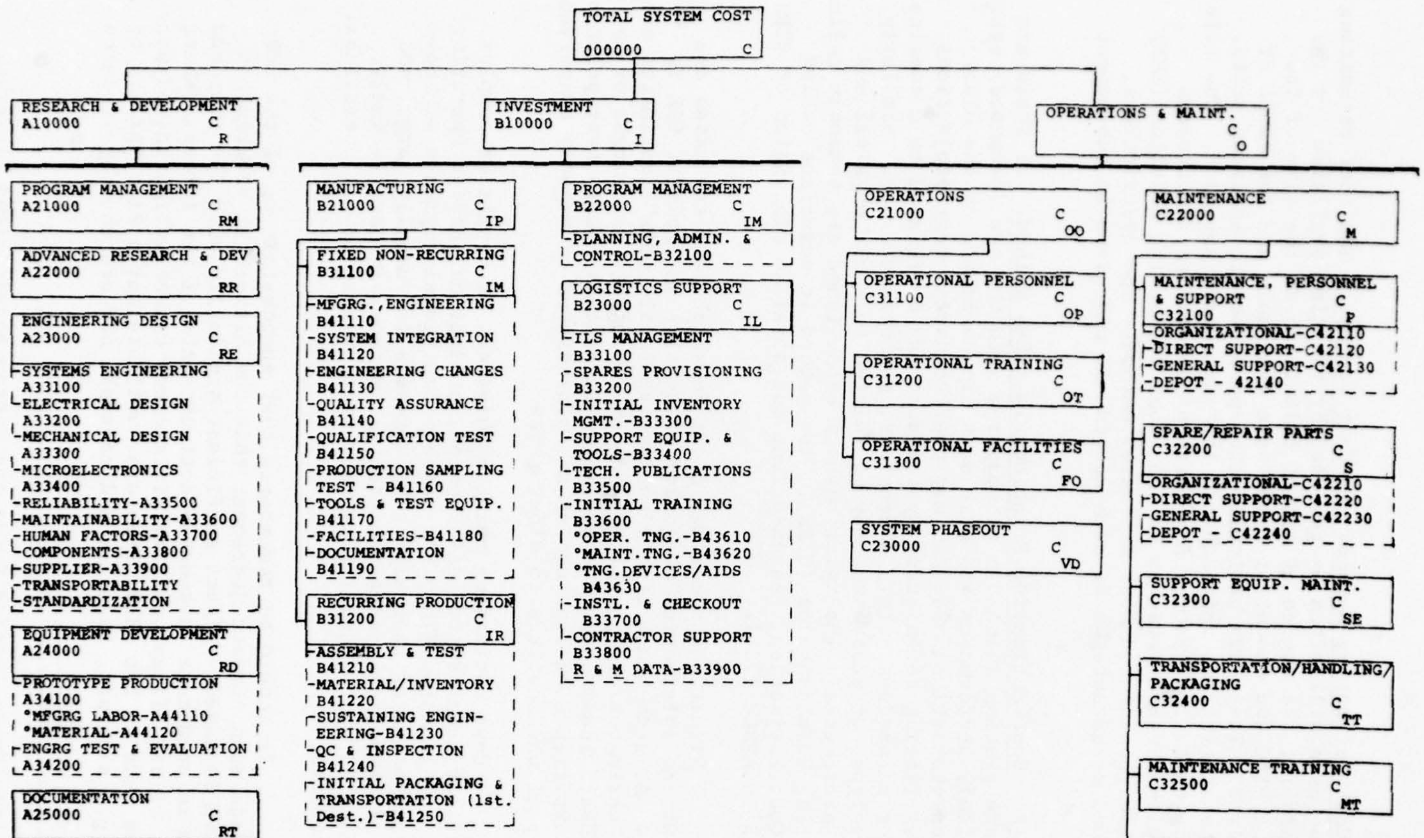


Figure 5-2

Program/Work Breakdown Structure Relationships



NOTE: Cost categories must be compatible with program work breakdown structure and cost reporting requirements and must be sensitive to analysis objectives.

Figure 5-3

Cost Breakdown Example

b. Cost Estimating Methods and Cost Factors. The cost estimating methods to be used will often be governed by the time available for the estimating effort, the degree of system definition at the time of the analysis, the kind and amount of input data available and the level of detail required. There are basically two approaches to estimate costs. These are the statistical approach and the engineered approach. The Life Cycle Costing Guide for Systems Acquisition[1] identifies the methods associated with these approaches as the "Cost Estimating Relation (CER)" method and the "Engineered Cost Estimate" method. The descriptions, advantages and disadvantages of each method are discussed in subsequent paragraphs.

(1) Cost Estimating Relationship (CER) Method. If there are prior hardware systems which can be compared with the new (proposed) system, and if physical, performance and cost data are available on the older systems, then statistical analysis may provide useful cost projections. Through curve-fitting techniques, system cost may be related to a combination of the system parameters, i.e., dimensions, performance, etc. Similarly, cost of some types of subsystems may be related to their physical and performance attributes. The relationships established are commonly called Cost Estimating Relationships (CERs). The method is sometimes called Parametric Cost Estimating. An excellent and detailed discussion of CERs is contained in AFSCM 173-1.

Situations sometimes occur in which cost estimates are required, but the information necessary to develop an explicit CER is unavailable. At such times highly subjective ("ball park") estimates are made. Such estimates are justified and can reasonably be thought of as "Implicit CERs," inasmuch as the estimator is subconsciously extrapolating from prior experience through use of an unformulated or vaguely conceived relationship of the new item to older items.

Cost estimating relationships can be simple or complex. They can reflect total system development, production, and/or operating and support (O&S) costs. They can reflect individual segments of those costs or a composite of them all. The segments are usually large, and the number of independent variables (or parameters) is usually small. Most CERs used in past acquisitions have omitted some or all operational and support costs.

It should be remembered that successful use of the CER method depends upon correct judgement that the historical programs on which the CER is based reflect sufficient similarity with the proposed new program to produce a reasonable cost estimate of the latter. Where the effects of significant program differences can be estimated, adjustments may be made to the CER. CERs are available for a wide variety of systems (e.g., aircraft, missiles and radars), and are used by research

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1. LCC-3, Life Cycle Costing Guide for System Acquisitions (Interim), January 1973.

and development personnel and cost analysts in the pertinent hardware areas. No general catalog exists, and the equations in use are generally non-standard or even treated as proprietary company information.

The CER method has several advantages. First, it may be used early because it can be, and usually is, based on broad performance parameters and configuration concepts, rather than on detailed design. Generally, its use should start during the Conceptual Phase. A second advantage is that, once developed, it can be rapidly and inexpensively employed. Hence it can be used for analysis of numerous possible design or program variations of a system.

The primary disadvantage of the CER method is that it is not applicable to radically new systems. The statistical relationships used are derived from experience, and that experience must be relevant to the new system. Hence, the new system must fit into an existing family of systems or be similar enough to such a family to justify use of the CER method, perhaps with some adjustment. The Cost Estimating Relationship method consequently may not produce reliable results for a system which depends heavily on new technology or incorporates drastically different design features.

There is currently a lack of development of operating and support cost cost estimating relationships sensitive to system design and other program parameters. However, there seems no reason to believe that aggregate O&S cost estimating relationships cannot be developed in the future for use even in early acquisition phases. Historical O&S cost data are gradually becoming more adequate to support statistical studies for the development of useful relationships.

(2) <u>Engineered Cost Estimate Method</u>. As information about the hardware system and its use increases, and as the DOD approaches decisions committing progressively larger amounts of money, more detailed life cycle cost estimating procedures become warranted and progressively more feasible. Total system cost is broken out into many elements, consisting of breakdown into finer details of hardware, functions, procedures, etc. The elements are related through cost equations which reflect in detail the way the elements interact when the system is developed, produced, operated and supported. The equations are expected to reflect the real world so closely that they can be said to be "engineered." They differ from the equations used in the regression analysis which create CERs. The "engineered" equations follow more closely the step by step cause-and-effect relationships in a close examination of the sequence of events in the real world. Regression analysis equations addressed to an identical cost aggregation deal with statistical patterns with less inherent capability to reflect departures from past conditions. The engineered cost equations are characterized by the need for many estimates of the values of the many elements and terms included. The individual value estimate subtotals and totals are examined and revised where and when the revisions will reflect improved knowledge of the anticipated design or costs.

Generally, use of the engineered cost estimate method becomes possible at about the same time it becomes needed from the standpoint of decision-making. Step by step, decisions on hardware and on operational and support concepts must be made, the timing of each being governed by leadtime considerations and prerequisite decisions in the overall acquisition process. As each decision is made, the latest (and presumably best) estimates are used concerning alternative implications for LCC and system effectiveness. Thus, there is a gradual transitioning from CERs to engineered cost estimates rather than a single changeover point for the entire system.

There are numerous reasons for employing the engineered cost estimate method as soon as conditions for its use have been met. One primary advantage is that it can be more accurate than CERs because it usually incorporates expert inputs at detailed levels. Different elements can be estimated by different people, and each element can be small enough to be within an individual's area of expertise and awareness of the latest information, such as test results and cost of proposed improvements. A closely related advantage is that the engineered cost estimate method can be applied independently to the various parts of the system. Hence, for system segments on which firmer descriptive information is available at an earlier stage, this cost method can be used to adjust or replace the results of the CER method. Another major advantage of the engineered cost estimate method is that it can contain enough detail to permit study of cost differences among competing functional proposals (for production, development, inspections, support procedures, etc.). Rules for use of the method should be clear and definite, so that proposals prepared accordingly can be compared. Sufficient specifics can be included that comparisons will illuminate specific functional areas and amounts of cost difference. Another important advantage is that the operating and support CERs have generally estimated O&S costs in ways that make them vary in the same direction as development and production costs. The engineered cost estimate, on the other hand, may properly reveal that certain increases in development and/or production costs can cause reductions in O&S costs.

The major disadvantage of engineered cost estimate methods is that they cannot be used effectively until detailed information is at hand. By that time, certain prior decisions have already eliminated some of the alternatives which now appear more attractive. A second disadvantage of the engineered cost estimate method is that it is generally more costly and more time consuming than the CER method. To have element estimates on a major system which are complete, up-to-date with new cost rates and design changes, and internally consistent can be a large assignment. Great care must be taken to avoid excessive details, i.e., cost elements whose impact on the system will be minor.

There is also a tendency for cost models prepared by the engineered cost estimate method to become large, complex and detailed. Another disadvantage is that the engineered cost estimate method is subjective in some cost inputs, and the effect of that subjectivity on reliability of subtotals and totals may be great. That drawback calls for careful review and credibility assessment.

(3) Cost Factors and Cost Data. The most tedious and time consuming part of the analysis is that of seeking out and gathering sufficient data. If a satisfactory life cycle cost analysis is to be performed, this process is both important and essential. In estimating costs, actual or estimated costs of analogous programs must be relied upon heavily. Most new programs do not represent a complete departure from the past, but embody improvements over previous programs, or involve new combinations of existing subsystems, major equipment and components. Therefore, it is generally desirable to identify the cost and cost-related performance, design, product and operating characteristics that represent carryovers from existing programs. Since life cycle cost places emphasis on consideration of ownership costs, data related to reliability, maintainability and availability are critical in order to estimate credible values for these factors.

There are many reliability and maintainability data sources. Within the Air Force, the AFM 66-1 Maintenance Data Collection (MDC) system (TO 00-20-2) and AFM 65-110 operational data are two major data collection systems. The following sources of data and others can provide a valuable tool in assessing reliability and maintainability and are described in AFLC/AFSCP 400-11.[2]

(a) Government/Industry Data Exchange Program (GIDEP), AFSC/AFLCR 80-27.

(b) Reliability Analysis Center.

(c) Systems Effectiveness Data System (SEDS) (DSD-B456).

(d) Materiel Deficiency Reporting System (TO-35D-54), AFR 60-30, AFLCM 66-15 (Chapter 12).

(e) Aerospace Vehicle Mishap Reporting System - AFR 127-13/AFLC Sup 1, AFLCR 127-3, AFR 127-4/AFLC Sup 1, AFLCM 66-15 (Chapters 10 - 14 and 19).

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2. AFLC/AFSC Pamphlet 400-11, Reliability and Maintainability Data Sources, 16 August 1974.

(f) Teardown Deficiency Reports (TDRs) (AFLCM 66-15, Chapter 14), Analytical Overhaul Inspections (ACIs) (AFLCR 65-25) and Analytical Condition Inspection Program (AFLCR 66-28).

(g) Standard Aerospace Vehicle and Equipment Status Reports (AFM 65-110).

(h) Maintenance Experience Data (TO 00-20-2).

(i) Increased Reliability of Operational Systems (IROS).

(j) Cost and Performance Analysis (CPA) (AFLCR 66-18, Chapter 20).

(k) Use of Item Operating Time in Materiel Management (DSD-G097).

(l) Actuarial Program for Selected Items (DSD-D057F).

(m) Missile Fleet Status Tool (MFST) (DSD-G078B, D, E, F).

(n) Aircraft Inertial Navigation System Performance, Test and Diagnostic Analysis System (DSD-G078C).

(o) Actuarial Products for Airborne Propulsion and Auxiliary Power Unit Management (DSD-D024).

(p) Electron Tube Management System (TO 00-20-8).

(q) Tire Improved Reliability Evaluation System (DSD-G011).

(r) Malfunction Detection, Analysis, and Recording System (MADARS)/Ground Processing System (GPS).

(s) Aircraft Structural Integrity Program.

There are also a number of documents and sources available that provide the average historical cost experience or other useful data. They include:

(a) USAF Cost and Planning Factors (AFR 173-10).

(b) USAF Statistical Digest.

(c) Bureau of Labor Statistics publications: Employment and Earnings: Wholesale Prices and Price Indices.

(d) Logistics Performance Data Books.

(e) A Guide for Estimating Aircraft Logistics Support Costs (AFLCP 173-3).

(f) Aircraft and Missile Depot Maintenance Cost Factors (RCS: HAF-ACM(A)7109).

(g) Estimating Depot Maintenance Cost for Air Force Aircraft (AFLCP 173-4).

(h) Maintenance Production Cost System (G072) (Depot Maintenance, Modifications).

(i) Appropriation General Ledger Account Cost Program (H057) (Spares, Munitions, Modifications).

(j) Base General Accounting System (H069) (Base Maintenance, Depot Maintenance, POL).

(k) Maintenance Labor Distribution (G037C) (Military Personnel, Base Maintenance).

(l) AFLC Retail Stock Control and Distribution System (D033) (Spares).

c. Cost Models and Life Cycle Cost Models. A recent literature search[3] revealed that there are numerous models available for addressing decision issues that affect life cycle cost. Some life cycle cost models have been developed to be used as general purpose analytical tools, while others have been developed to meet specific program or analysis needs. Some models have been designed for application to a weapons system, while others have been designed for specific types of subsystems/equipment (e.g., avionics). These models and their uses vary in many ways. Therefore, in order to gain better insight into the various attributes of different life cycle cost models, the Life Cycle Cost Working Group defined eight separate categories of models based primarily on the type of use for which each model was initially designed. These eight categories are:

(1) Accounting Model - A set of equations which are used to aggregate components of support costs, including costs of manpower and material, to a total or subtotal of life cycle costs.

(2) Economic Analysis Model - A model used in the problem of choosing how to employ scarce resources and in investigating the full implications of achieving a given objective in the most efficient and effective manner.

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3. Analysis of Available Life Cycle Cost Models and Actions Required to Increase Future Model Applications, Joint AFSC/AFLC Commanders' Working Group on Life Cycle Cost (ASD/ACL), December 1974.

(3) Cost Estimating Relationship Model - A model relating life cycle cost or some portion thereof directly to parameters that describe the design, performance, or operating environment of a system.

(4) Reliability Improvement Model - A model that reflects the relationship between equipment reliability and cost.

(5) Level of Repair Analysis Model - A model that determines, for a given piece of equipment, a minimum cost maintenance policy from a set of policy options that typically include discard at failure, repair at base and repair at depot.

(6) Maintenance Manpower Planning Model - A model that evaluates the cost impact of alternative maintenance manpower requirements or the effects of alternative equipment designs on maintenance manpower requirements.

(7) Inventory Management Model - A model that determines, for a given system, a set of spare part stock levels that is optimal in that it minimizes the objective function, such as system spares costs, Not Operationally Ready Supply (NORS) rate, expected backorder rate and Operationally Ready (OR) rate.

(8) Warranty Model - A model used in assessing the cost effectiveness of warranty related decisions such as optimal warranty period and breakeven costs.

Representative currently available models in each category and experience to date in implementing these models are also described in Appendix C.

Cost and life cycle cost models are mathematical equations which relate a desired cost, the total life cycle costs in the case of LCC models, to either partial cost elements or other factors affecting the desired cost. Since so many factors affect costs, many cost models are relatively complex. Symbols, generally letters or combinations of letters, often with subscripts, are used to designate each factor in the equations. In addition, the equations include the normal arithmetic symbols. Seldom do they involve any mathematics beyond algebra.

d. Learning Curves and Cost Quantity Relationships. For many years the aerospace industry has made use of what variously has been called a "learning," "progress," "improvement," or "experience" curve to predict reductions in cost as the number of items produced increases. The learning process is a phenomenon that prevails in many industries; its existence has been verified by empirical data and controlled tests. Although there are several hypotheses on the exact manner in which the learning or cost reduction can occur, the basis of learning curve theory is that each time

the total quantity of items produced doubles, the unit or cumulative average cost is reduced to a constant percentage of its previous cost. The learning curve is used for a variety of purposes. AFSCM 173-1 provides a detailed description of cost-quantity relationships, their development and their use.

e. Treatment of Inflation. Because estimates for inflation in future years are often important in a time-phased tradeoff study, the analysis and evaluation of each study should specifically consider inflation. To determine and access the effect of changes in the purchasing power of the dollar, both constant dollars (without inflation) and current dollars (with inflation) should be considered in analyzing and evaluating alternatives.

To assure consistency, the first estimate of costs and cost benefits, i.e., savings, should be made for each year of the planning period in terms of constant dollars. Any forecast change in the general price level during the planning period should not be included.

If inflation is an important factor in the study, a second computation in terms of inflated dollars should be made. Using the constant dollar estimates as a baseline, inflation should then be included, either by using price indices or by application of a uniform inflation rate. When there is reason to believe that price levels for different costs, e.g., procurement, RDT&E, etc., will significantly vary, the indices available for these categories should be used. This second computation should take into account the following:

(1) To avoid overestimating and double-counting for the effect of inflation, such factors as contract provisions that may already provide for inflation, labor agreements, productivity and quantity changes, and the extent to which material is already on hand, or will be furnished under a fixed price contract should be considered.

(2) Whenever practicable, estimates should include forecasts of changes in price levels on the basis of specific data applicable to a given acquisition. The source of the inflation factors and the indices used for each year should be included.

(3) The estimates of inflation should be identified by fiscal year. When including inflation in a cost estimate for more than 4 years beyond the budget year, be aware of the uncertainty in making a valid economic forecast, and the fact that values for inflation may change considerably.

5-3.3 Engineering and Other Analysis Methods

a. Logistics Support Analysis (LSA). LSA is the process of analyzing a given or assumed system/equipment design configuration to determine specific logistics support requirements in terms of: maintenance functions/tasks, repair levels, spare/repair part types and quantity, personnel skills and quantity, support and test equipment, facility requirements, technical data requirements, transportability, handling/packaging requirements, etc. LSA may be accomplished on any system or equipment and in any program phase to varying degrees of depth depending on the need and extent of their available system/equipment definition. Initially, in early phases of system/equipment definition, data is limited and sketchy. Allocations and gross level predictions are necessary to accomplish the required analysis. As the program progresses, additional data (analytical data replaces prediction data, field data replaces designed analytical data, etc.) becomes available, and the analysis results are more meaningful. MIL-STD-1388, Logistics Support Analysis, establishes requirements for LSA integral to the system engineering process.

b. Maintenance Engineering Analysis (MEA). MEA is an integral by-product of the system engineering process. Maintenance requirements (failure modes and frequency) are derived from reliability/design analysis and are used in turn to determine repair procedures, task time, manhours, tools and skills. MEA is a systematic process of recording/documenting the maintainability analysis required by MIL-STD-470 and integrating function between design and logistics support requirements. MEA and level of repair analysis (LOR) are the principle functions of LSA. It is from this total process that quantification and determination are made of repair levels, source codes, the maintenance plan, spare requirements and the balance of logistics requirements. MEA provides important failure rate and time to repair data for life cycle cost computations.

c. Failure Mode and Effects Analysis (FMEA). FMEA is a technique used to achieve a balanced design on an item before it is committed to production. The FMEA looks at each part within the unit and determines what happens if the part fails. In this manner, one can design to eliminate potential catastrophic failure modes and also eliminate extra parts or ones that are used to achieve more performance than is necessary. The FMEA has the advantage of forcing one to cover all possibilities, i.e., what happens if either success or failure is encountered. FMEA is an important part of a design review because it considers failures related to the manufacturing processes, as well as the basic design.

d. Level of Repair Analysis/Optimum Repair Level Analysis (ORLA). Level of Repair Analysis is a term assigned to an analysis technique which establishes (1) whether or not an item should be repaired; (2) at what maintenance level it should be repaired, i.e., organizational, intermediate or depot; or (3) if the item should be discarded. ORLA uses analytical models to determine the most economical level of repair for components and subsystems. Input data is provided for such analysis by the MEA process. ORLA procedures are explained in AFLCM/AFSCM 800-4.

e. Trade-Off Analysis. Trade-off analysis is a very general term describing a wide variety of activities related to evaluating design or other program alternatives in terms of variations in cost, performance and schedule. Of particular concern in life cycle cost analysis is how life cycle costs vary as a function of different levels of performance.

f. Logistics Performance Factors (LPFs) and Related Analyses. AFLC Pamphlet 800-3 identifies standard factors for use in analyzing and quantifying logistics performance during system acquisition. These factors have several uses, including enhancing communication between the logistician and the design engineer, thereby influencing the design to improve supportability. This pamphlet provides historical logistical performance factors by system and functions. It also provides graphic techniques and tools for trade studies. This pamphlet discusses the major problems in defining and applying LPFs during the life cycle and suggests that, while performance in a test environment and that in the operating environment are not likely to agree, much improvement can be made in understanding the reasons for differences, in reducing such differences where possible, and in applying a common perspective in the use of the factors. This, in turn, can help in developing more realistic life cycle costs.

Figure 5-4 is a schematic of the availability and use of key LPFs during the significant periods in the life cycle. The factors and formulae are grouped under availability (A), reliability (R), maintainability (M), and logistics (L) or supportability. Pertinent directives are indicated where applicable. Both lateral and vertical relationships of these items are shown. For example, inherent (or design) reliability ($MTBF_i$) is used as a subfactor in the equation for inherent availability (A_i). The operational mean time between demand (MTBD) is a derivative of the mean time between removal (MTBR). Laterally, the factors and their formulae are shown under the life cycle categories, i.e., requirement, design, test, production and operational. For reliability, the factors and formulae are also shown in relationship to the functional breakdown, i.e., allocation, prediction, verification, degradation, field experience and product improvement activities.

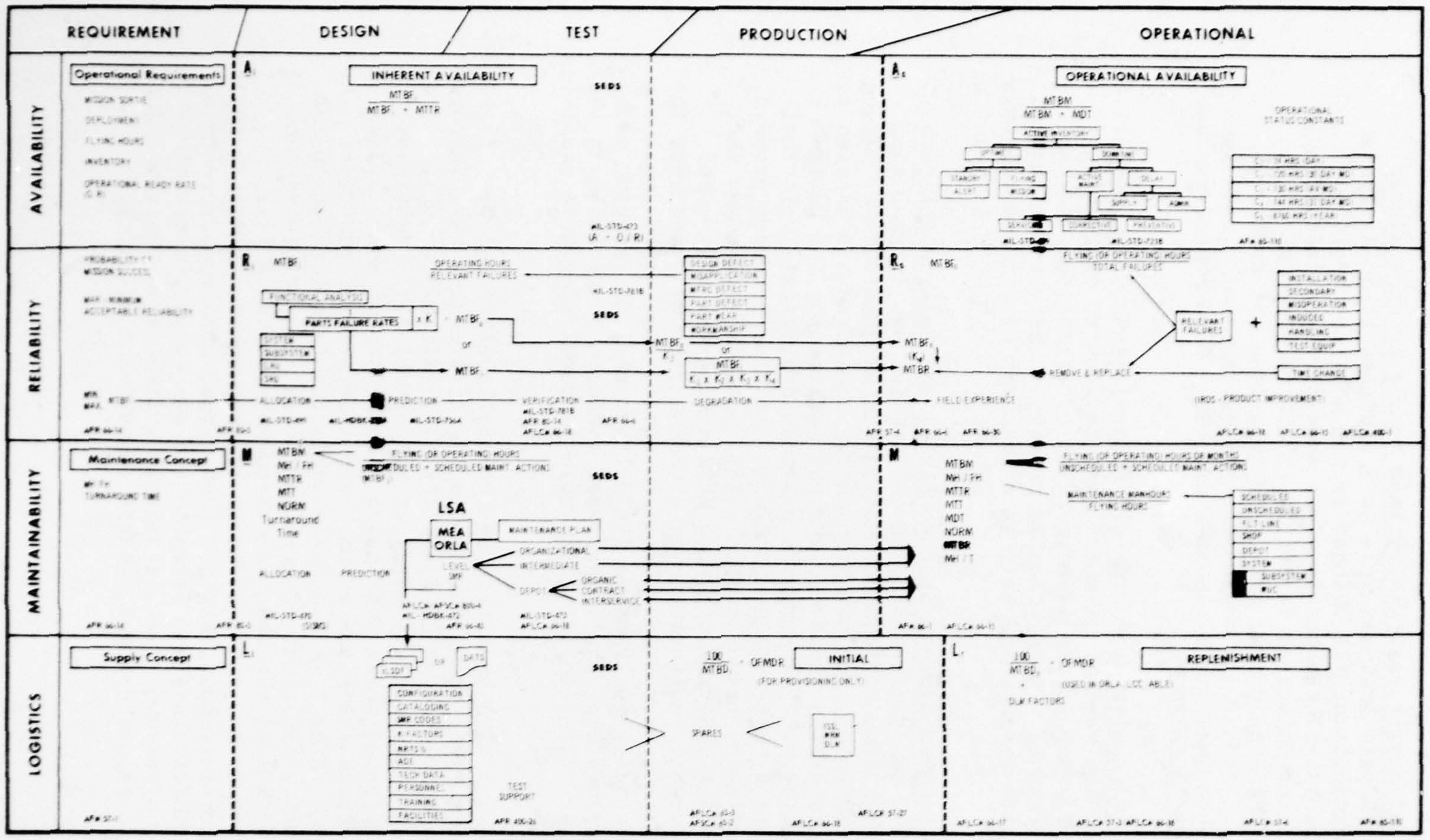

Figure 5-4

Logistics Performance Factors--Acquisition Through Life Cycle

Source: AFLCP 800-3

(1) Availability. This parameter (A) expresses the probability of the system being up and ready to accomplish the design mission when required. It is a function of the operational requirements and primarily dependent upon the frequency of failure (MTBF) and the length of downtime in clock hours (MTTR) to correct a failure (unscheduled maintenance). Inherent availability (A_i) is derived directly from inherent (or design) reliability (R_i) and MTTR. Availability is usually expressed as operational availability (A_o). (DOD ILS Guide, AFP 800-7 and MIL-STD-473.) The latter differs from A_i in that the frequency of all maintenance tasks is considered (both unscheduled and scheduled maintenance (MTBM)), and the total maintenance downtime (MDT) includes both active and inactive administrative or supply delay time.

(2) Reliability. Reliability (R) is a principal performance factor influencing design and life cycle costs, since it is the lead factor in determining other factors such as availability, maintenance load factors (MLFs) and spares and support requirements. MTBF has occasionally been considered synonymously with MTBM or MTBD with erroneous results.

Figure 5-4 is intended to facilitate a clearer understanding of the factor audit trail and interrelationships. Overall system R is stated in terms of mission success and minimum acceptable reliability (MAR) values. Conceptual allocation or percentage distribution to functional systems (2 X WUC) level is outlined in AFR 66-14, Attachment 1. Specific reliability requirements will normally be stated in the specification for the hardware. The design function includes functional analysis, using block diagrams and parts failure rates, leading to reliability calculation and prediction ($MTBF_i$). MIL-HDBK-217B shows in detail how to implement the requirements of MIL-STD-756. Parts failure rates are provided based on controlled test data (vendor, laboratory, qualification). This will produce a pure design $MTBF_i$. However, K factors based on field data are also provided for correcting parts failure rates for application resulting in modified $MTBF_i$ which at least partly expresses $MTBF_o$. MIL-STD-756 also provides a like K factor for correcting an initial $MTBF_i$.

Two other areas must be considered in translating $MTBF_i$ to $MTBF_o$. Vendor development and production tests are normally based upon actual equipment operating time (for example, using an Elapsed Time Indicator (ETI) or event counter (EC)). In most instances, operational reliability is based on flying hours times QPA. The ratio may be less than, equal to, or greater than unity (for example, .80, 1.00, 2.30), depending upon the application, installation and operational use of the hardware. Reference AFR 66-6 and AFLCM 66-15 for use of ETIs/ECs in more precise measurement of $MTBF_o$. The other area concerns the distinction between relevant failures and total failures.

Relevant failures (MIL-STD-781B) are limited to those directly related to the vendor's design and production process and are essentially those for which he is contractually responsible and accounted for in the $MTBF_i$ factor calculated during development and test. When a vendor item (set, line replaceable unit (LRU), shop replaceable unit (SRU)) is installed in the end item and operated and maintained in the operational environment, additional failures are generated for other reasons, many beyond the control of the vendor. Total failures generate a demand for maintenance and spares and increase downtime beyond that calculated using only relevant failures, and an adjustment factor is required in translating $MTBF_i$ to $MTBF_o$. The ratio of relevant to total failures is influenced by the learning curve which causes the K factor and $MTBF_o$ to be variable factors during the life cycle. The K factors used in MIL-HDBK-217B should adjust for relevant versus total failures since they are based on field data.

(3) Maintainability. This parameter (M) is a quantification of design for ease of maintenance. Maintainability is a consideration of design, while maintenance is a consequence of design. The primary measurements of M are MTTR, mean task time (MTT), and/or maintenance downtime (MDT), all of which express elapsed time (usually in clock hours) to accomplish unscheduled maintenance. Maintenance manhours/flying hour (MMH/FH) is commonly used as a quantification expression of maintainability. This factor includes a frequency parameter (MTBF or MTBM) and is referred to as MLF since this value is oriented toward maintenance workload requirements and distribution in relation to amount of activity. Documentation of the design analysis and successive updates provide the necessary data base for logistics management. Maintainability prediction (MIL-HDBK-472) is a tool for design enhancement because it provides for early recognition and elimination of areas of poor maintainability during design. Maintainability data is collected and evaluated during development and suitability testing (MIL-STD-473, AFRs 80-5 and 80-14) to determine achievement of design requirements and supportability of the system.

(4) Logistics. The logistics/supportability spectrum of logistics performance factors applies in a restrictive manner to those factors used in determination of spares. Reliability and maintainability are basic characteristics of supportability. Spare requirements are determined primarily by hardware reliability, although influenced by total maintenance requirements, maintenance practice and supply support. An integrated planning effort is required during the conceptual and development phases, i.e., the supply support plan must be consistent with the maintenance plan and repair level decisions. The maintenance factor (OFMDR) is generally based on item MTBF. By definition a "recurring" demand for a spare arises only as a result of removal of a defective item and replacement by a serviceable item from supply stock. This can be due

to both failures and directed or time change maintenance actions. The MTBF excluding removals for access, cannibalization, and those found serviceable (action taken code B) most closely indicates the MTBD related to spare requirements.

5-3.4 Analysis Methods for Management Decisions

a. Uncertainty, Treatment Of. Although risk and uncertainty are frequently used as equivalent terms, a useful distinction may be made between them. A risk situation is one in which the outcome is an uncontrollable random event stemming from a known probability distribution. For example, the toss of a coin involves a risk with a 0.5 probability of a head turning up. An uncertain situation is characterized by the fact that the probability distribution of the uncontrollable random event is unknown.

Making useful cost predictions of future weapon systems varies in complexity and difficulty, depending upon the degree of definition and specification of the system and the availability of pertinent historical cost data in suitable form for processing. Whenever possible, cost estimates should identify the degree of uncertainty and anticipated risks which could significantly affect costs. The sources of uncertainty and risks are many and are often difficult to identify and describe. Generally, the sources of uncertainty can be related to either system definition or cost estimating methods.

Uncertainties with respect to the system definition may be minimized by initially obtaining a clear understanding of and continually tracking the specific configuration, quantities planned, procurement and production schedules and operational concept. Program and design changes which must be tracked and assessed include:

(1) Engineering Changes. These changes include altering the physical or functional characteristics of a system or item after an initial baseline is established. These change orders normally occur over the life of the program. They tend to have a cumulative effect on the whole program and lead to spares and spare parts obsolescence, schedule delays and, in general, increased program costs.

(2) Quantity Change. A quantity change may impact the total cost of the buy, as well as unit and average cost, schedule, production efficiency and contractual agreement. The fiscal year distribution of funds may also be affected.

(3) Support System Change. A change in support item requirements (spare parts, training, ancillary equipment, warranty provisions, Government-furnished property/equipment, testing) may result in changes to engineering design, quantity, or logistics concepts.

(4) Schedule Change. A change in delivery schedule, completion date, or intermediate milestone of development or production will usually impact the total program cost and the fiscal year distribution of funds. When a schedule changes, the analyst must consider the impact of such items as overtime, production efficiency, and inflation.

(5) Policy Changes. Policy changes may impact significantly on the cost estimates. Thus, the concepts in effect when the estimates are made should be clearly identified. For example, procurement policy variables, such as make or buy, Government Furnished Equipment (GFE) versus Contractor Furnished Equipment (CFE), etc., are many and often affect costs.

Uncertainties with respect to cost estimating concern data and their treatment. The major causes of estimate uncertainty are inability to measure cost precisely, inadequacy of applicable data, statistical uncertainty, errors or inconsistencies in the treatment of these data and errors of judgement. The cost analysis has four objectives in treating cost estimating uncertainties:

(1) Reduce the uncertainties surrounding the estimate.

(2) Assess both the reasons for and the dollar impact of remaining uncertainty.

(3) Convey the degree of uncertainty to the estimate's user.

(4) Guide the user in interpreting the estimator's conclusions.

b. Risk, Treatment Of. Figure 5-5 shows the theoretical situation of estimating system costs, wherein all economic, technical and program factors have been completely and accurately forecasted. During the Conceptual Phase, a single estimate of system cost may be constructed as shown by the vertical line. Each program acquisition cost estimate has expected errors resulting from both technical and program uncertainties and from those statistical processes used in prediction. Adding together the expected errors for the remaining acquisition phases (all of them in this case) produces the typical probability curve (curve A). The original single point estimate still has the greatest probability of occurring; it is the expected value of the system cost. However, significant variations in system cost also have high probability of occurring. There are then some small probabilities that the true system cost will deviate by large amounts from the central point estimate. As program acquisition proceeds, fewer phases remain to be estimated and the corresponding range of

possible error is reduced. There is less anticipated error in the Validation estimate and even less in the Full-Scale Development estimate. Since the assumption was made that the point estimate was accurate, the curves are centered on the same vertical line. The heights of the curves are different because the areas underneath the curves have been set equal.

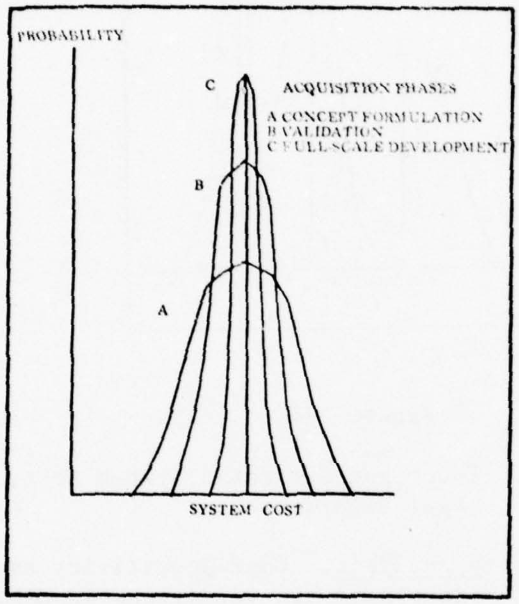

Figure 5-5
Probability of Incurring Estimated System Cost, Theoretical

Figure 5-6 gives the system cost estimate situation that experience shows can be expected. The error widths about the estimates are still the same, because the number of phases still to be estimated remain the same. However, subsequent cost estimates increase. This gap in our knowledge is due to the fact that, while the error range due to predicted cost variances decreases as the program proceeds, the point cost estimate may increase to reflect new knowledge, unanticipated changes, escalation, early unwarranted options or other factors.

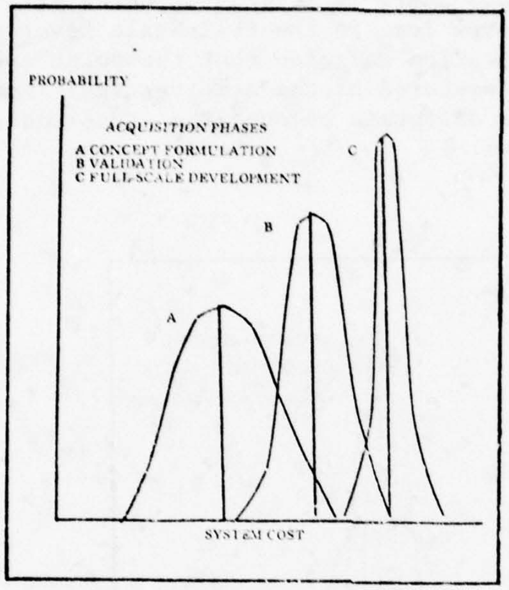

Figure 5-6

Probability of Incurring Estimated System Cost,
Past Experience

c. Cost Sensitivity Analysis. Cost sensitivity analysis is an analytical procedure for determining how variations in other program parameters affect resource requirements including costs. Cost sensitivity is frequently used in cost-effectiveness studies to attempt to reflect and assess uncertain analysis inputs or assumptions. The analyses are performed to help the system designer or the program manager identify:

(1) Elements that are cost sensitive.

(2) Areas in which system performance can be upgraded without increasing program cost substantially.

(3) Areas in which design research is needed to surmount substantial cost obstacles to achieving higher program performance.

(4) The total cost impact of uncertainties in the considerations of a program.

Cost sensitivity analysis may be conducted at varying levels of detail during any phase of system acquisition.

d. Cost-Benefit Analysis/Cost Effectiveness Analysis. A cost-benefit analysis is an analytical approach to solve problems of choice and resource allocation. It requires the definition of objectives, the identification of alternative ways of achieving each objective, and the identification, for each objective, of that alternative which yields the required level of benefits at the lowest cost. The same analytical process is often referred to as cost effectiveness analysis when the benefits or outputs of the alternatives cannot be quantified in terms of dollars. In either form of analysis, qualitative and quantitative factors, foreseeable secondary or side effects and non-economic benefits are explicitly considered.

e. Economic Analysis (DODI 7041.3/AFR 178-1). Economic analysis is one form of cost-benefit analysis and is a systematic approach to the problem of choosing how to best employ resources. The determination of efficiency and effectiveness is implicit in the assessment of the cost effectiveness of alternative approaches and is accomplished by:

(1) Systematically identifying and quantifying the benefits and other program outputs and costs associated with alternative programs, missions and functions and alternative ways of accomplishing a given program.

(2) Highlighting the sensitivities of a decision to the values of the key variables and assumptions on which decisions are based including technical, operational, schedule and other performance considerations.

(3) Evaluating alternative methods of financing investments, such as lease or buy.

(4) Discounting both costs and benefits to make all alternatives more comparable with respect to their economic consequences.

(5) Using benefits and costs to compare the relative merits of alternatives, as an aid in:

(a) Establishing or changing priorities.

(b) Recommending the cost-effective alternative.

(c) Making trade-offs between alternatives.

f. Discounting and Present Value Cost Analysis. It is likely that the cash-flow will be different for each year during the development and acquisition of a system. Recognition and analysis of differences in the timing of investment and recurring cost cash flows of the alternatives is accomplished through the use of discounting. After an estimate of the cash-flow has been developed for each

alternative, the present value (discounting) technique should be used to compare costs on a more equitable basis. The present value or total discounted annual cost is developed for each alternative using annual cost data and appropriate discount factors. DOD currently prescribes the use of a 10 percent rate; however, cost analyses may include a test of other discount rates. Discount factors for the 10 percent discount rate are listed in Table 5-1. A computation format such as shown in Figure 5-7 is used for these computations. Column d is the sum of the input cost data in columns b and c. Column e is taken from Table 5-1. Column f is the product of columns d and e. The column f total is the present value of the alternative. Additional information on the nature and use of discounting is contained in AFR 178-1 and DODI 7041.3.

DISCOUNT FACTORS

PRESENT VALUE OF $1 (Single Amount. To be used when cash-flows accrue in different amounts each year.)

Project Year	*10%*
1	0.954
2	0.867
3	0.788
4	0.717
5	0.652
6	0.592
7	0.538
8	0.489
9	0.445
10	0.405
11	0.368
12	0.334
13	0.304
14	0.276
15	0.251
16	0.228
17	0.208
18	0.189
19	0.172
20	0.156
21	0.142
22	0.129
23	0.117
24	0.107
25	0.097

Table 5-1*

*Factors are based on continuous compounding of interest at the stated effective rate per annum, assuming uniform cash flows throughout stated 1-year periods. These factors are equivalent to an arithmetic average of beginning and end of the year compound amount factors found in standard present value tables.

a.	b.		c.	d.	e.	f.
	Nonrecurring					
Project Year	R&D	Invest-ment	Recurring Operations	Annual Cost	Discount Factor	Discounted Annual Cost
1. 2. 3. . . 25.						
Totals						

Figure 5-7

Present Value Computation Format

5-3.5 Important Life Cycle Cost Analysis Related Terms

a. Design to Cost (DTC). Design to Cost is defined in DOD Directive 5000.28 as a management concept wherein rigorous cost goals are established during development, and the control of systems costs (acquisition, operating and support) to these goals is achieved by practical trade-offs between operational capability, performance, cost and schedule. Cost, as a key design parameter, is addressed on a continuing basis and as an inherent part of the development and production process.

Initial goals for Design to Cost for aircraft systems are to be established in the form of average unit flyaway cost. Consistent with ability to translate operating and support cost elements into "design to" requirements, Design to Cost goals should also be established for these elements.

Although the Design to Cost goal generally includes only flyaway cost, the management objective during development must still include the control of future operating and support costs. The major operating cost factors (e.g., those related to manpower, reliability, maintainability, etc.) which contribute significantly to life cycle costs should have goals established in the form of measurable numbers which can be monitored during test and evaluation as well as operation. Unit cost, total acquisition and O&S cost trade-offs should be examined during development to insure that the new system being introduced to the force structure will have the least total life cycle cost.

Design to Cost goals are established during the conceptual phase, at program initiation (DSARC I), or at the earliest practical date thereafter, but not later than the time of approval for entering into full scale development (DSARC II). An initial estimate of the resources available for allocation to the program is made, and cost

objectives are established during concept formulation. As soon as the system is definitized to the extent that costs associated with minimum performance needed can be estimated with reasonable confidence, a firm Design to Cost goal will be recommended and, upon approval by the Secretary of Defense, will become the official Design to Cost goal for the program. The Design to Cost goal is a highly visible cost goal under which the program manager must strive to obtain acceptable results and upon which, in large measure, the success of the program and the cost performance will be measured. As the program nears DSARC II, the Design to Cost goal will be validated or updated.

An initial life cycle cost estimate will generally be established at the initiation of the validation phase, or at the earliest practical date thereafter. This estimate is to be used as a basis for cost trade-off analyses when considering acquisition versus O&S costs, comparing competing prototypes or comparing current versus new systems. It should also be used to focus management attention on the O&S cost impact of bringing a new system into the operating inventory. Life cycle cost estimates will be updated prior to the initiation of the full scale development phase and the production phase of a program.

Proposed changes to the established Design to Cost goal for major programs must be approved by the Secretary of Defense, normally after review and recommendation by the DSARC. They will generally be approved only for major changes in program structure or mission requirements, for changes where a significant demonstrable reduction in life cycle costs can be achieved, or for other program changes beyond the control of the program manager or military department. Design to Cost goals for other than major programs are to be similarly established and controlled. Approval authority for these cost goals and changes to these goals will be maintained at a management level above the program manager.

The program manager is responsible for ensuring that provisions for Design to Cost principles and goals are included in request for proposals and contracts. He is also responsible for allocating the program Design to Cost goal among the various system elements. In applying the Design to Cost concept to a new system, it is essential that a determination be made of the minimum performance, reliability, maintainability and force levels, which are required to assure the needed capability, in order to allow the maximum flexibility for subsequent trade-offs of performance, schedule and costs.

Design to Cost programs are to be reviewed periodically on a life cycle cost basis. This review should include the effect of specific elements in the life cycle cost management approach, such as source selection factors, contract incentives, the use of cost models and warranties, and test and evaluation plans, to measure specific life cycle cost factors.

b. Should Cost. Should cost is a concept of contract pricing that employs an integrated team of Government procurement, contract administration, audit and engineering representatives to conduct a coordinated, in-depth cost analysis at the contractor's plant. The purpose is: (1) to identify uneconomical or inefficient practices in the contractor's management and operations and to quantify the findings in terms of their impact on cost; and (2) to develop a realistic price objective which reflects reasonable achievable economics and efficiencies. It is DOD policy that a should cost study be conducted on systems or items requiring DSARC approval.

c. Sunk Costs and Incremental Costs. If costs have been incurred as a result of past decisions they are known as sunk costs. Sunk costs should not be included in cost calculations used for decision analysis. Sunk costs do not reflect results of pending decisions and alternatives. Their consideration in the analysis would only confuse the decision making problem. The analysis should present only the future costs or savings, sometimes called marginal or incremental costs, of each alternative under consideration. These are those increments of cost that will be incurred as a result of choosing one or another of the alternatives available.

d. Figures of Merit. Figures of merit involve some system measure or series of measures unique to each system. In one instance, such as ballistic missiles, operational availability may be paramount, while in others, reliability, maintenance manhours per flying hour, shop turnaround time, may be more appropriate. The nature and extent of test and demonstration activities will be based on the figures of merit which are most appropriate for each specific system.

5-3.6 Contract Incentives. In order to motivate contractors to innovate to reduce life cycle costs and to submit realistic life cycle cost estimates for their designs, a range of incentive types described in ASPR 3-400 can be applicable to major system acquisitions. Because of the complexity of these acquisitions, special care must be taken in the selection of incentive types and the structuring of those incentives to avoid a situation in which the motivation is ultimately toward those things which are not of the greatest importance to the Government or are actually harmful to the best interest of both parties. Generally, in the earlier phase of development, the less structured incentives, particularly award fees, are most appropriate. By full scale development, the system definition and design should have matured sufficiently to accommodate more rigorous approaches. The key element in successful application of these types of incentives is the ability to measure achievement of the parameters which are incentivized. Incentives for minimizing operating and support costs have also been developed and applied. They generally required that an estimate of part of all of the support costs associated with a system or equipment be included in the contract as a target. These same costs are subsequently measured under field conditions to see how well the contractor designed and built the system with respect to meeting the target costs. These types of contractual provisions include:

a. Award Fee Provision. A very flexible provision giving the contractor opportunity to obtain an award fee of specified maximum size if the measured cost related values meet or exceed the specified target values, or if actions to reduce costs exceed expectations.

b. Price Adjustment Provision. A contract provision by which the contract price may be adjusted either upward or downward in accordance with a prearranged formula based on the results of a verification test. This is often referred to as a positive/negative incentive provision. The contract normally contains a provision for the contractor to propose no cost engineering change proposals to resolve problems preventing the contractor from meeting his projected life cycle cost. In the event of a negative price adjustment, the method of payment is usually accomplished through the following options or combinations thereof at the discretion of the contracting officer: (1) refunding dollars, (2) providing additional units, (3) providing additional replaceable items and (4) correction of deficiencies.

c. Logistics Support Cost Commitments Provision. A contract provision which requires the contractor to initiate a corrective course of action to bring the logistics costs within the prescribed target. These actions may involve implementation of no cost engineering change proposals (ECPs) or provide additional assets at no additional cost to the Government.

d. Reliability Improvement Warranty (RIW) Provision. A contract provision specifying that, for a fixed price, the contractor is encouraged to improve the reliability and to reduce the repair cost through the mechanism of no cost engineering change proposals (ECPs). The RIW provision may contain an MTBF guarantee option in which the contractor may be required to continue his obligation under the RIW at no cost to the Government until the MTBF guaranteed values equal or exceed the measurements for specified measurement periods. The contractor may also be required to provide loaner spares for observed MTBFs differing from those originally bid in accordance with a prearranged formula.

e. Operating and Support Cost Factor Incentive Provision. A contract provision which places a direct incentive on operating and support cost drivers such as reliability and maintainability. Whenever it is practical, the degree of success in meeting the targets should be measured under early operational use and conditions.

AD-A069 392 JOINT AFSC/AFLC COMMANDERS' WORKING GROUP ON LIFE CYC--ETC F/G 5/1

LIFE CYCLE COST ANALYSIS GUIDE, (U)

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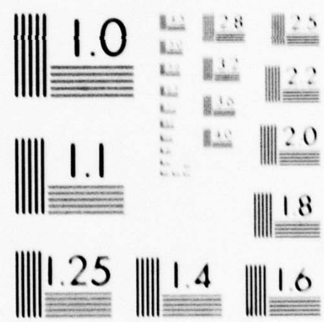

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Appendix A

Life Cycle Cost Plan Preparation Guidance

INTRODUCTION

This Appendix outlines an approach to the development of a program Life Cycle Cost Plan. Preparing such a plan consists of identifying an integrated set of specific tasks for controlling and reducing life cycle costs. Guidance contained herein addresses who is responsible for the Plan preparation, what the Plan should address, and when and how it should be prepared.

LIFE CYCLE COST PLAN DEFINITION

A Life Cycle Cost Plan is a document which provides the integrated plan for the time phased activities required to accomplish a specific set of life cycle cost objectives. It is a dynamic document subject to revision and change as the implementation of the Plan evolves.

RESPONSIBILITIES FOR LIFE CYCLE COST PLAN PREPARATION

The Program Director/Manager is ultimately responsible for the Life Cycle Cost Plan. Representatives of the supporting commands (usually AFLC and ATC) and using commands (MAC, SAC, TAC, etc.) should actively participate with procurement, engineering, financial and logistics program office personnel in the Plan preparation. Implementation of the plan is enhanced if the participants are subsequently responsible for tasks to be accomplished. However, when this approach cannot be taken, it is important that the appropriate parts of the Plan are submitted to responsible organizations for final review and coordination. The Life Cycle Cost Plan development team leader normally will be assigned from the projects office.

ORGANIZATION OF THE LIFE CYCLE COST PLAN

In organizing the Life Cycle Cost Plan, a logical approach is to document the program life cycle cost objectives and describe the plans and actions necessary to implement these life cycle cost objectives. The program manager may tailor the format and detail to fit the particular program; however, the Life Cycle Cost Plan should address: (1) the overall objective of the Plan; (2) a list of specific life cycle cost objectives; (3) a description of tasks to be accomplished to meet each objective; and (4) a description of procedures with which to manage and integrate the activities so as to assure timely and effective achievement of the specific objectives. All activity descriptions should include <u>what</u> is to be done, <u>who</u> is to do it, required <u>resources</u> and important <u>milestones</u>. A suggested Plan organization is outlined below:

<u>Preface</u>. Reflects the Program Manager's approval of the Plan and endorsement by the using and supporting commands.

Section 1.0 Introduction

1.1 Purpose. Describes what the Plan does and the overall objective of its preparation. Emphasis should be on controlling and reducing life cycle costs and on providing visibility on the progress of specific tasks and objectives.

1.2 Background. Briefly describes the background of the program and its objectives.

1.3 Program Schedule. Highlights the major program milestones and activities, past and present, for each phase of the program.

1.4 Scope. Describes the Life Cycle Cost Plan approach, scope and contents.

Section 2.0 Life Cycle Cost Objectives. Describes normally eight to ten life cycle cost objectives concerning areas such as management goals, life cycle cost goals, cost as a design parameter, system requirements, employment concept, design sensitive life cycle cost models, contract provisions, source selection criteria, and operation and support cost visibility.

Section 3.0 Tasks and Procedures. Describes the specific tasks to be accomplished and procedures to be implemented. Each task must support one or more of the life cycle cost objectives contained in Section 2.0. A matrix correlating the tasks to the objectives may be useful.

3.1 Management Approach

3.2 Tasks

3.2.1 Requirements Definition Studies

3.2.2 Employment Concept Studies

3.2.3 Life Cycle Cost Goals

3.2.4 Life Cycle Cost Assessment Plan

3.2.5 Trade Studies

3.2.6 Non-Quantitative Factors

3.2.7 Engineering

3.2.7.1 Avionics

3.2.7.2 Engines

3.2.7.3 Structures

3.2.7.4 Software

3.2.7.5 Simulators

3.2.8 Production

3.2.9 Testing

3.2.10 Logistics

3.2.11 Procurement

3.2.11.1 Contract Provisions

3.2.11.2 Source Selection

3.2.12 Training

3.3 <u>Procedures</u>

3.3.1 Life Cycle Cost Tracking

3.3.2 New Ideas

3.3.3 Analytical Activities

3.3.3.1 Cost Analysis Cost Estimating (CACE) Analyses

3.3.3.2 Hardware Design Analyses

3.3.3.3 Manpower Analyses

3.3.3.4 Support Analyses

3.3.4 Trade Studies Guidelines

3.3.5 Goal Adjustment Criteria

<u>Section 4.0</u> <u>Resources and Schedule</u>. Addresses manpower required, funding for contract studies, if appropriate, and the schedule for the accomplishment of the tasks outlined in the Plan. A chart listing each task, the task OPR, and the schedule for accomplishing each task should be included.

<u>ORGANIZING TO PREPARE THE PLAN</u>

There are any number of ways to organize to prepare a Life Cycle Cost Plan. One person may be given the responsibility for pulling together inputs from responsible organizations and formulating the results into an integrated plan. Another approach is to establish a formal steering group and working group to acnieve the same objective. Utilizing a steering group and working group nas

the advantage of having active participation of representatives from many organizations. This promotes greater commitment and involvement in life cycle costing and should expedite review and coordination of the Plan by all organizations involved. Life Cycle Cost Plan preparation should begin early in the program to facilitate the integration of life cycle cost considerations into the system engineering and design process. Regardless of the organizational approach, the Plan preparation effort should capitalize on experience from other programs and include contractor and using and supporting command inputs.

UNDERSTANDING DIRECTION AND GUIDANCE

Program background documents and related direction and guidance should be reviewed. The objective is to ensure that all participants in the preparation of the Plan become thoroughly familiar with the program objectives, direction and guidance. Sufficient knowledge must be obtained on all facets of the system that impact life cycle cost. Among these are the employment concept including operational and support concepts, performance requirements and goals, and schedules. Of particular importance is a clear understanding of how the system requirement, design or operation can or might significantly differ from past programs.

DEFINING LIFE CYCLE COST OBJECTIVES

A set of specific life cycle cost objectives must be developed and clearly stated. This task should be accomplished in coordination with the Program Manager. If a Steering Group has been established, the Steering Group should provide the Working Group an outline of the specific Life Cycle Cost objectives. The Working Group should refine these objectives, propose new objectives or recommend deletion of objectives, based on the potential ability to define manageable tasks to implement the objectives. An early Steering Group review of progress toward defining meaningful objectives should be accomplished. However, it should be recognized that specific Life Cycle Cost objectives will evolve throughout this planning effort. Several areas that normally will be covered by specific objectives are management goals, life cycle cost goals, cost as a design parameter, system requirements, employment concept, design sensitive life cycle cost models, contract provisions, life cycle cost awareness, source selection criteria, and operating and support cost visibility.

OBTAINING AND EVALUATING DATA

As a basis for establishing definable manageable tasks it is useful to search out on-going and recently completed projects in the various areas. Projects such as the Maintenance Posture Improvement Program, Software Studies, Studies on Tailoring Specifications and Standards, Avionics Advisory Board efforts and Support Equipment Standardization Group efforts provide very useful information upon which specific tasks can be developed. Experience from other programs is also a very valuable source of data. Lessons learned from other program problems and high cost areas warrant special consideration. This phase of the planning effort is the most time consuming, but potentially the most fruitful. Since sources of information are virtually unlimited, it is important that this effort

be well organized and constrained by a reasonable planning schedule. Working Group members' backgrounds and experience should be used as a basis for assigning each member specific plan preparation tasks.

DEFINING SPECIFIC TASKS

The Working Group should evaluate the previously identified individual study efforts to establish specific program tasks and in doing so, must consider the specific life cycle cost objectives to be achieved and resource constraints. If a Steering Group has been established, progress should be reviewed on a periodic basis. The Steering Group should provide leads and guidance to the Working Group in areas that have not been adequately addressed. It is important that during this phase of the effort communications be established with the organizations and/or contractors who will participate in accomplishing the tasks. Implementation of the tasks is facilitated if the responsible organizations participate in finalizing the definition of the tasks they are to accomplish.

REVIEW AND COORDINATION OF THE PLAN

Whether or not the responsible organizations participated in defining the tasks, the Plan should be submitted for their final review and coordination. Since this plan represents the Program Manager's approach to manage life cycle costs during the acquisition program, his approval should constitute program management direction. The Plan should also be endorsed by the using and supporting commands. This endorsement constitutes commitment on their parts to provide the resources required to implement the Plan.

REVISING THE PLAN

Plans should be made for revising and changing the Plan. This requires the designation of an Office of Primary Responsibility (OPR) to oversee the implementation of the Plan and identify the need for revision and changes. The Steering Group, if one has been established, can accomplish this function as well as oversee further changes to the Plan.

101

Appendix B

Planning, Programming, and Budgeting System Overview

INTRODUCTION

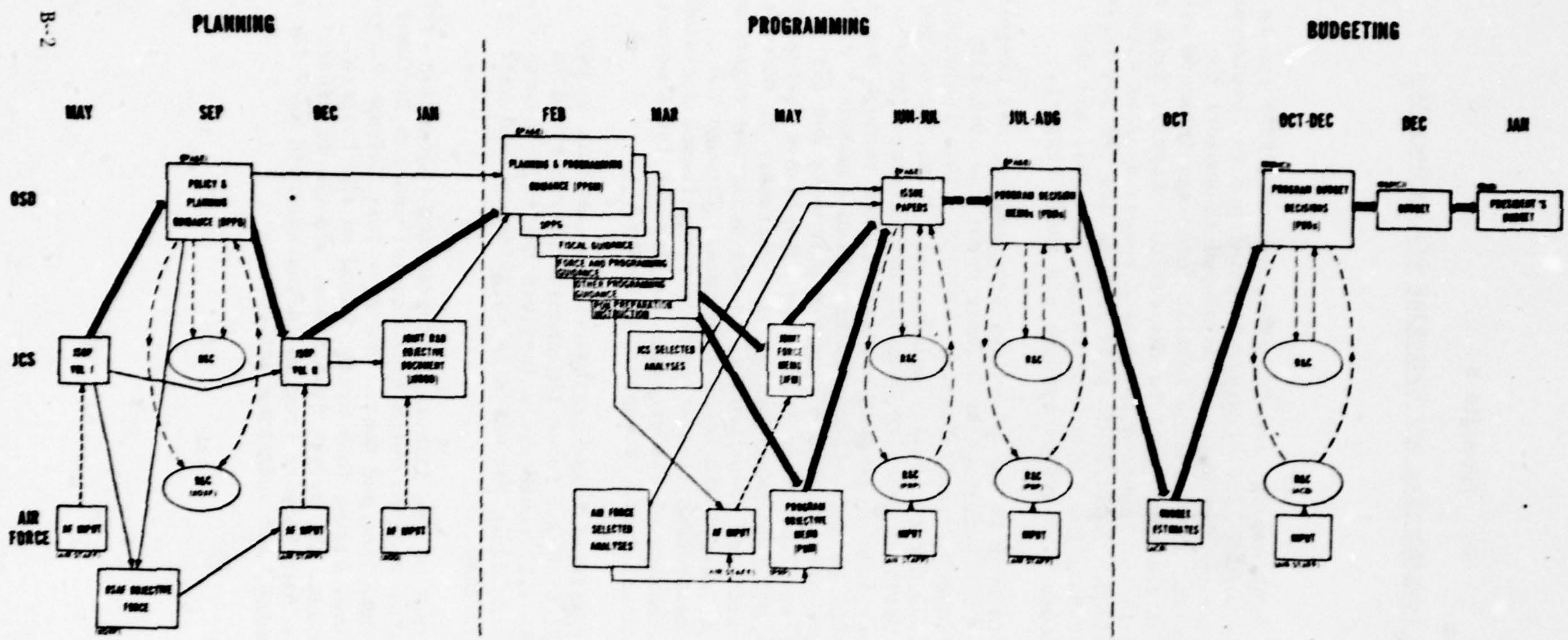
The Planning, Programming, and Budgeting System (PPBS) can be summarized in a few words. The strategy is developed in consideration of the threat. Force requirements are developed to support the strategy. Programs are developed to fulfill force requirements with due consideration of the total cost to the nation. Lastly, funds must be budgeted to obtain the required forces and weapon systems within the resources provided. Implicit in this process are the development of mid-range objectives, the conduct of special studies, and the research and development of weapon systems and their support.

Decisions pertaining to the planning, programming, and budgeting process are made by the Secretary of Defense under the authority granted by the Defense Reorganization Act of 1958. This legislation gave the Secretary, under the policy guidance and direction of the President and the National Security Council, two distinct lines of authority. A direct line of command was established through the Joint Chiefs of Staff (JCS) to the unified and specified commands. A line for administrative control of the military departments and for management of support of military forces was established through the Secretaries of the Military Departments. The Secretary of Defense, utilizing the command line of authority, issues decisions regarding threat appraisal, strategy, and force structure. Through the administrative or management line of authority, he issues decisions regarding the programming of resources to support the force structure and budgeting of annual funds to support programs.

The PPBS's organization and procedures are embodied in DOD Instruction 7045.7, with Air Force implementation contained in AFR 27-9. The PPBS's 18 month cycle involves the major events shown in Figure B-1, the schedule for which is established each year by the Secretary of Defense.

The final output of the planning, programming, budgeting cycle is the Five Year Defense Program which contains information in three dimensions: Program, Time, and Cost. The Five Year Defense Program is published three times during this cycle, based on the Program Objectives Memorandum, the Budget Submission, and the Presidential Budget. This Five Year Defense Program is the approved base for all planning, programming, and budgeting action.

PLANNING, PROGRAMMING, & BUDGETING SYSTEM (PPBS)[1]



1 ESTABLISHED BY DOD INSTRUCTION 7045.7, AND IMPLEMENTED BY AFR 27-1

R&C = REVIEW AND COMMENT

JSOP = JOINT STRATEGIC OBJECTIVES PLAN

(XOD) DIRECTOR OF DOCTRINE, CONCEPTS & OBJECTIVES, DC/S PLANS & OPERATIONS
(PRP) DIRECTOR OF AEROSPACE PROGRAMS, DC/S PROGRAMS & RESOURCES
(ACB) DIRECTOR OF BUDGET, COMPTROLLER OF THE AIR FORCE
(XOXF) DEPUTY DIRECTOR FOR FORCE DEVELOPMENT DC/S PLANS & OPERATIONS

Figure B-1

PLANNING

Planning, the first phase of the Planning, Programming, and Budgeting System, starts with the assessment of the threat to the security of the United States and culminates with the projection of force objectives to assure the security of the United States. The projection of force objectives is limited only to feasibility of forces in being and capabilities of research and production to obtain forces in the future. The major portion of the planning effort is accomplished within the Joint Chiefs of Staff area. The civilian officials of the Military Departments have no assigned or assumed responsibilities in the planning phase of the Planning, Programming, and Budgeting System. The planning concept is to assess the world situation (friend and foe) at prescribed future time periods, technical capabilities required, military strategy to counter threats to the national security, and to state force objectives to satisfy the national strategy.

Major Events (Figure B-1)

° The primary planning document is the Joint Strategic Objectives Plan, Volume I, Strategy and Force Planning Guidance. This document translates national objectives and policies into military objectives. It describes the forces necessary to accomplish these objectives and prescribes the strategic concepts for the actual employment of these forces. The Joint Strategic Objectives Plan I covers a time span of nine years, beginning after the current fiscal year.

° The Secretary of Defense makes tentative decisions and responds to the JCS and Services with the Defense Policy and Planning Guidance.

° Based on this Guidance the JCS develop the Joint Strategic Objectives Plan, Volume II, Analysis and Force Tabulation.

° Next, the Joint Research and Development Objective Document is prepared which provides the advice of the JCS to the Secretary of Defense concerning capabilities expected to be needed in the 10-20 year period.

PROGRAMMING

The purpose of the programming phase is to translate the approved concepts and objectives, prepared during the planning phase, into a definitive structure expressed in terms of time-phase resource requirements including men, monies, and materiel. This is accomplished through systematic approval procedures that "cost out" force objectives for financial and manpower resources five years into the future, while at the same time displaying forces for an additional three years. In order to increase the information that can be obtained from the Five Year Defense Program regarding decisions that must be made during a weapon

system acquisition cycle, the Services are now required to submit Extended Planning Annexes as part of their Program Objectives Memorandum. The annexes are an attempt by the Services to answer the question of how much they are planning to pay from the procurement account from the 6th to the 15th year to buy the things that are being developed now and gives the Secretary of Defense, the Congress and the President an idea of the impact that present day decisions have on the future defense posture.

Major Events (Figure B-1)

- The primary programming document is the Planning and Programming Guidance Memorandum. This Memorandum prescribes the Defense Policy and Force Planning guidance, Fiscal guidance, Logistics and Materiel Support Planning guidance and Program Objective Memorandum preparation guidance. The fiscal guidance indicates overall dollar constraints within which programs are to be developed. Based on anticipated DOD dollar resources, the Memorandum projects the allocation of funds five years into the future by major mission and support categories for each of the military departments.

- After completing the force structure plans and in response to the Defense Planning and Programming Guidance, the JCS issues a Joint Force Memorandum. The Joint Force Memorandum presents force level and support program proposals responsive to the fiscal guidance. The Joint Force Memorandum contains a JCS assessment of the risks associated with reducing the recommended forces to meet fiscal guidance. It also highlights the major issues to be resolved during the coming year.

- The services submit their proposals for a service program in terms of forces and manpower and rationale for changes to the approved five-year defense program base in the Program Objective Memorandum. The Program Objective Memorandum presents each service's views of force alternatives within the constraints of fiscal guidance.

- OSD prepares Issue Papers which form the basis for the Secretary of Defense decisions in the forthcoming Program Decision Memoranda. Each issue paper defines the issue, notes the alternatives and evaluates the capabilities and cost of alternatives in terms of the ability to implement the DOD strategy. The JCS and Services review the Issue Papers for accuracy and completeness and provide comments.

- The Secretary of Defense issues his decisions on force and program changes in the form of Program Decision Memoranda. There is a provision for the Services to express dissenting views to any of the Secretary's program decisions. The Secretary directs appropriate staff reviews, and any new decisions resulting from such reviews are reflected in modified Program Decision Memoranda.

BUDGETING

The budget process is the final phase in the Planning-Programming-Budgeting Cycle. The annual budget expresses the financial requirements necessary to support the approved forces and programs set forth under the first program year of the Five Year Defense Program. While derived from the Five Year Defense Program, budgets are expressed in greater refinement and detail than the Five Year Defense Program. The approved programs are those which evolve from incorporating all decision documents received through a predetermined date announced by the annual Program/Budget review schedule memorandum. It is through the budget that planning and programming are translated into annual funding requirements. Each year's budget estimate, therefore, sets forth precisely what the DOD expects to accomplish with the resources requested for that year. The budget process is divided into three phases:

Formulation - planning and developing the budget for the fiscal year. The formulation phase begins when a call is issued for budget estimates to the defense components. This call is based on guidance from the Assistant Secretary of Defense (Comptroller). The formulation phase continues with review, modification, and with amendment, and final approval by the Secretary of Defense, the Office of Management and Budget (OMB), and the President.

Justification - presenting and justifying to the Congress the budget for the next fiscal year.

Execution - obligating and expending Congressionally appropriated funds for the current and prior fiscal years.

Budgets are formulated, justified and executed on the basis of appropriation. Appropriations are subdivided into budget activities sub-heads, programs, projects, etc. The format and structure of the various appropriations are controlled by Congress and represent the manner in which Congress desires the agencies and departments to express requirements for funds.

Major Events (Figure B-1)

- The final program decisions are included in the budget estimates of each Service.

- The Secretary of Defense directs a staff review of the budget estimates and publishes a series of Program/Budget Decisions. These are transmitted to the Services for insertion into the Five Year Defense Program. Reclama statements may be submitted if the impact is considered sufficiently serious to warrant the personal reconsideration of the Secretary of Defense.

- The culmination of these events results in the President's Budget.

Appendix C

Descriptions of Representative Life Cycle Cost Models

I. ACCOUNTING MODELS

The most familiar category of life cycle cost models is the accounting model, e.g., a model that computes the logistics portion of the life cycle cost of a weapon system or subsystem as a function of logistics parameters. This type of model is characterized by computations for such cost categories as spares and maintenance, which may initially be computed at relatively low levels of indenture, for example, for individual First Line Units (FLUs). The model primarily sums these different costs for each FLU as well as other cost categories, hence, the generic classification accounting model.

A. THE AFLC LOGISTICS SUPPORT COST MODEL[1]

Objective of Model: The objective of the AFLC Logistics Support Cost (LSC) model is to estimate the expected support costs that may be incurred by adopting a particular design. The model is used to compare and discriminate among design alternatives where relative cost difference is the desired figure of merit. The significance of the results, therefore, is not based on the absolute value of support costs, but on the magnitude of the cost difference *among* alternatives. In this regard, the LSC model is not, strictly speaking, a life cycle cost model, although it is one of the many specialized models used to support life cycle cost analysis. The LSC model is intended for application in three different areas: (1) to obtain an estimate of the differential logistics support costs between the proposed design configurations of two or more contractors during source selection; (2) to establish a baseline for contractual commitments on certain aspects of operational supportability which will be subject to verification; and (3) to use as a decision aid in discriminating among design alternatives during prototyping or full-scale development.

Model Description: The model computes an estimate of logistics support cost as a function of five categories of data elements:

1. Program elements, i.e., data characterizing flying hour programs, deployment and operating scenarios, etc., that are furnished by the Government.

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1. "Logistics Support Cost (LSC) Model User's Handbook," AFLC/AQMLE, Wright-Patterson AFB, Ohio 45433.

2. Contractor-furnished system elements, i.e., estimates of costs such as cost of special depot facilities that are not directly associated with first line units but nonetheless contribute significantly to overall system-level cost.

3. Contractor-furnished FLU elements, i.e., estimates of parameters such as mean flying time between maintenance action (MFTBMA) that are based on characteristics of the design of the FLU.

4. Propulsion system elements, i.e., for those defense systems that include propulsion systems, data such as mean engine operating time between removals (contractor-furnished) and engine repair cycle time at base and depot levels and fuel costs (Government-furnished).

5. Government-furnished standard elements, i.e., elements such as labor rates, inventory costs and repair cycle times.

The basic LSC model consists of ten equations or submodels, each of which represents a cost of resources necessary to operate the logistics system. The ten cost components are:

1. Initial and replenishment FLU spares cost.

2. On-equipment maintenance cost.

3. Off-equipment maintenance cost.

4. Inventory management cost.

5. Support equipment cost.

6. Personnel training cost.

7. Management and technical data cost.

8. Facilities cost.

9. Fuel consumption cost.

10. Spare engines cost.

Examples of Model Use and Prospects for More Extensive Use: To date the LSC model has been used by several program offices as a vehicle for considering LCC trade-offs and for estimating logistics support costs. Some examples of its use are:

1. To compute a support resources estimate that was used as a primary source selection criterion in selecting the B-1 electronic countermeasures package.

2. To compare alternative avionics packages for the B-1 on the basis of support resource impact.

3. To compute the LSC effects of proposed ECPs for the B-1.

4. To identify candidates (i.e., high consumers of support resources to be agreed upon by the Government and the eventual FSD contractor) for either a follow-on Reliability Improvement Warranty (RIW) or a correction of deficiencies clause.[2] A modified version of the model was used during the Full Scale Development (FSD) source selection of the Air Combat Fighter.

The LSC model has been found to have certain disadvantages associated with its use. The principal disadvantage is the lack of an accurate set of historical data to estimate costs on an analogous basis. This results in the need to use multiple data systems which were designed for purposes other than weapon system cost accounting. For example, the base level maintenance data collection system is largely a production control monitoring and scheduling system. Because of the diverse sources of data, only partial weapon system support cost visibility is available. A great deal of prorating of common expenses applicable to several weapon systems exists. A companion problem exists in the practice of managing both depot level maintenance and supply by National Stock Number (NSN), base level supply by NSN, and base level maintenance by Work Unit Code (WUC). The fact that there is no direct one-to-one mapping of NSN to WUC serves to further aggravate the data problem, especially at the component level.

The difficulty of using the LSC model to validate estimates of support resources given the above problems becomes rather apparent. The effects on model output of uncertainties associated with the input values are further clouded as costs are aggregated. When the LSC model is used as a source selection tool based on input parameter estimates having considerable uncertainty, the resulting estimate should be exposed to sensitivity analyses to isolate input values that have a critical effect on the estimate.

B. THE AFLC OPERATIONS AND SUPPORT (O&S) COST MODEL[3]

The objective of the AFLC O&S cost model is the same as that of the AFLC LSC model. The two models both estimate support cost as a function of logistics parameters. They differ in minor respects, e.g., the LSC

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2. Additional details are contained in the Life Cycle Cost Provisions of the F-16 contract. A copy of these provisions is in the ASD/ACL library.

3. A full description of this model is included in a report, "Review of the Application of Life Cycle Costing to the A-X/A-10 Program (1970-1973)," ASD/ACL, October 1973.

model breaks down cost to the FLU level for SE whereas the O&S cost model does not. The O&S cost model was used for full scale development source selection on the A-10 program.

C. USAF COST ESTIMATING MODELS[4]

These models differ substantially from the accounting models described previously. Nonetheless, they are included in the accounting model category because, like the accounting models above, they use the building block approach to estimate costs. The fundamental difference between these models and the LSC and O&S cost models is that they do not compute operating and support costs directly for individual subsystems and FLUs. Rather, they estimate costs using cost factors for spares, support equipment, manpower, etc., that are found in various tables of AFR 173-10. These factors are given either as a function of the number of flying hours or the number of aircraft. Cost estimates obtained from these models are based on extrapolations of these factors based on similar or analogous weapon systems, and not on specific design and performance characteristics of the weapon system for which an estimate is being made. However, these models include many support costs (base operating, medical, factors for UPT/UNT training, pipelines, vehicles, etc.) not considered in other support cost models.

The Planning, Programming and Budgeting Annual Cost Estimating (BACE) Model: The primary purpose of the BACE model is to develop aircraft squadron annual operating cost estimates for Planning, Programming and Budgeting (PPB) exercises and related studies. The BACE model uses a building block approach to estimate annual operating costs. Results reflect variable operating, support and recurring investment costs associated with such programming data as unit equipment (UE), flying hour programs, crew ratios and manpower. The estimates reflect the allocation of identifiable program costs to aircraft squadrons. The BACE model computes Primary Program Element (PPE) costs, Base Operations Support (BOS) costs, Depot Maintenance Costs and Program VIII Personnel Support and Training Pipeline costs.

Cost Analysis Cost Estimating (CACE) Model: The CACE model provides cost analysts with sufficient flexibility to permit use in various types of studies. In general, it represents a further step in identifying the marginal cost of operations. In addition, it can serve as a vehicle for introducing new factors or estimating techniques. The CACE model may be used for cost or research analyses, life cycle cost exercises, or studies concerned with cost effectiveness comparisons between weapon systems. Like the BACE model, it also uses a building block approach. The CACE model is not to be used for Planning, Programming and Budgeting (PPB) exercises or related studies. The CACE model computes Recurring

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4. Descriptions of the models are contained in AFR 173-10, USAF Cost and Planning Factors.

Investment and Miscellaneous Logistics Costs, Pay and Allowances (P&A), Base Operating and Support (BOS) and Real Property Maintenance (RPM) costs in support of the Major Force Program (MFP), Medical (MFP VIII) costs, Military Personnel Support costs and Military Personnel Pipeline costs.

Missile Annual Cost Estimating (MACE) Model: This model is similar to the CACE model just discussed except it is for use in costing missile squadrons. Its use is appropriate for the same type of cost studies as the CACE model. The MACE model computes costs in two parts using the same major cost categories as the CACE model for each part. Part A is for the missile and Part B is for the missile site support aircraft.

The Planning Aircraft Cost Estimating (PACE) model, a predecessor to these models, has been used recently to develop an operating and support cost estimate for a Defense Systems Acquisition Review Council (DSARC III) decision on the A-10 aircraft and DSARC II on the F-16 aircraft. It is also being used by McDonnell Douglas on contract to the F-15 Program Office for O&S cost estimates. The CACE model is the generally accepted Air Force format for preparing operating and support cost estimates for submission to the DSARC.

D. OSD COST ANALYSIS IMPROVEMENT GROUP (CAIG) OPERATING AND SUPPORT COST DEVELOPMENT GUIDE FOR AIRCRAFT SYSTEMS[5]

This guide was prepared by the CAIG for use by service and CAIG analysts in preparing new aircraft system operating and support cost estimates for DSARC review. This guide defines O&S cost elements, prescribes methodologies and illustrates reporting formats. The major cost elements are squadron operations, base operating support, logistics support, personnel support and recurring investment. Like the USAF cost estimating models, it uses data developed from past operational experience and program data that describe the size of the aircraft unit, the aircrew composition and annual unit activity rates.

E. SIMPLIFIED MAINTENANCE COST MODEL[6]

The Joint AFSC/AFLC Commanders' Working Group on Life Cycle Cost, in conjunction with the Deputy Chief of Staff for Acquisition Logistics, Air Force Logistics Command, has requested a service test of a possible

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5. A copy of the guide is available in the ASD/ACL library. Specific questions concerning guide development and cost estimating procedures should be addressed to either Mr. Frank Swafford (OASD(PA&E)) or Mr. Ron Porter (OASD(PA&E)).

6. Additional information can be obtained from ASD/ACL, Wright-Patterson AFB, Ohio 45433.

new data system designator to be generated quarterly for the purpose of running the REDUCE model (described under Economic Analysis Models). Additionally, it has been determined that certain data elements from this proposed product can be used to produce a gross estimate of annual maintenance costs (including special repair activity costs, pack/ship costs, condemnation costs and, where possible, base material costs). The simplified model requires only six input data parameters:

1. Mean time between failure (MTBF), using the AFLC Panel 34 definition of failure.

2. Mean time between other-than failure-related maintenance actions (MTBO).

3. Cost per failure.

4. Cost per non-failure-related maintenance action.

5. Quantity per application.

6. Quarterly force flying hours.

The model computes the total annual and unit annual maintenance costs and ranks the maintenance costs for each component or subsystem, from the most expensive to the least expensive. The simplified maintenance cost model has three major potential uses. First, it can be used to compare maintenance cost estimates for proposed designs with actual maintenance costs of existing designs. Such comparisons can be used for source selection evaluation guidance or any other evaluation where relative rather than absolute maintenance cost estimates are useful. The word "relative" is emphasized here because, among other reasons, there presently exists little field experience data on base material costs, one of the components of the cost per failure figure used in the model. Second, the simplified model can be used to assess the maintenance cost implications of test results and then used to track estimated maintenance costs of new equipment. Third, since the model separates those costs attributed to actual failures from those attributed to other maintenance actions, it goes one step beyond the current K051 (IROS) data system. This additional piece of information should prove useful in pinpointing whether high support costs are the result of poor reliability or non-failure-related problems.

F. OTHER ACCOUNTING MODELS

"A Life Cycle Cost Model for Inertial Navigation Systems." This model was used to compare alternative inertial navigation systems for the B-1 bomber in 1972. It is currently being used by avionics engineers at the Aeronautical Systems Division (ASD/ENA) to compare not only inertial navigation systems but also other avionics equip-

ments on the basis of life cycle cost. Most of these more recent applications of the model have been in the context of retrofitting decisions.[7]

A more detailed life cycle cost model for use with respect to inertial systems and ultimately all avionics is currently under development by the Life Cycle Cost Task Group of the Joint Services Data Exchange (JSDE) Group for Inertial Systems. One of the central goals of this model is to provide a common framework for use by the three services and all inertial systems contractors when estimating life cycle cost. It should provide all participants in the inertial system procurement process with a common language for discussing life cycle costs in order that more valid comparisons and more accurate judgements might be made on the basis of life cycle cost.

"UHF Modernization Radio Program (ARC-XXX) Life Cycle Cost Model." The ARC-XXX/ARC-164 program was the first major subsystem procurement in which life cycle costing was the primary factor in source selection. The contractors were required to submit life cycle cost estimates using a standard government supplied life cycle cost model. A complete description of this model is contained in the Life Cycle Costing Special Provisions of the ARC-164 contract. This model is also discussed in a report titled, "Review of the Application of Life Cycle Costing to the ARC-XXX/ARC-164 Program." A copy of both of these documents is in the ASD/ACL library.

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7. Further information on this application of the AGMC model is available from ASD/ENA, Wright-Patterson AFB, Ohio 45433.

II. ECONOMIC ANALYSIS MODELS

An important function where analytical models can be put to good use in the Air Force is the determination of the economic implications of decisions to modify or augment the capabilities of current weapons systems. Retrofit decisions typically raise the issue of whether or not to spend funds in early years to achieve savings in later years. Mathematical models can be used to evaluate the economic implications of alternative retrofitting programs and can lead to decisions that reduce life cycle cost in the long run. The REDUCE model described below is an example of an economic analysis model.

REDUCE: AN AIRCRAFT SUBSYSTEM ECONOMIC ANALYSIS MODEL[8]

Objective of Model: To serve as a tool for evaluating the USAF forcewide economic implications of proposed alternative new and retrofit aircraft equipment programs.

Model Description: REDUCE (Research into the Economics of Design and User Cost Effects) can be used to compute the life cycle cost implications of:

1. An aircraft retrofit program in which new equipment with different reliability and maintainability characteristics will replace presently installed equipment performing the same function, on all or selected aircraft in the Air Force inventory.

2. Alternative new equipment proposals providing different equipment designs for performing additional functions on existing aircraft or specific functions on new aircraft.

3. Changes in operating and maintenance policies.

When comparing the relative economic merits of alternative designs for a proposed new equipment item, the model considers estimates of RDT&E, acquisition/installation, and maintenance costs over the full life of the system. In the case of a retrofit program, the model produces comparisons between the life cycle costs of a proposed new item and the support costs of the items it would replace. It also provides the capability for exploring tradeoffs between the investment of money in RDT&E to improve an item's reliability and maintainability characteristics and consequent savings in maintenance costs during the

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8. Cerone, James R., et al, "The REDUCE Model: Description," Caywood-Schiller Division, A. T. Kearney, Inc., July 1972; ASD/XR-72-34; prepared for Deputy for Development Planning, ASD/XR, Wright-Patterson AFB, Ohio 45433. For additional information contact ASD/ACL, WPAFB, Ohio.

the item's operating lifetime. The model uses discounting procedures to calculate the present values of future program costs and also has the capability to consider inflation and estimate out year costs in then-year dollars. The model provides a variety of output formats designed for both budget and decision analysts.

The model is composed of the following major components:

1. A data base needed to describe the scope of future operations; the equipment configuration of each aircraft series to be considered for retrofit; and reliability, maintainability, and cost factors of equipment items currently installed in these aircraft.

2. The INIT module which establishes a data base in a computer storage-compatible format initially and updates the data base after it has been established.

3. The ACOUT module which produces output formats containing information required to make decisions concerning item replacement.

4. The SETUP module which transforms inputs on a proposed new item into computer records that can be operated on by other modules.

5. The RETROFIT module which evaluates the life cycle cost effects of proposed retrofit programs.

6. The NEW vs NEW module which computes and compares the life cycle costs of several alternative new items being considered for performing a given function.

Potential Model Applications: The model requires considerable input data. The effort required to obtain this data is most easily justified for a complex problem involving the possible use of a new improved piece of equipment on several aircraft types over a long period of time. It is ideally suited to economically evaluate the potential value of standardization of new and low maintenance cost subsystems throughout the Air Force.

III. COST ESTIMATING RELATIONSHIP MODELS

Cost estimating relationships (CERs) are mathematical equations that express the total or specified partial cost of a system or equipment directly as a function of (1) physical properties (e.g., accuracy, volume or parts density) of the system/equipment or (2) properties of the operating environment in which the system/equipment will be used (e.g., deployment scenario, flying hour program or aircraft environment). They are typically derived by using statistical regression to fit cost data on existing similar systems and equipments to the data that reflect physical or environmental properties for these systems and equipments. Their advantage over accounting models is two-fold. They can be developed and used early in the conceptual and preliminary design stages of RDT&E to study the effects on cost of varying these properties and, hence, to compare alternative requirements on the basis of cost. They can be used to obtain preliminary estimates of cost when details of design or operating and support concepts are not yet known.

Cost estimating relationships have frequently been used in recent years to estimate the acquisition costs of new Air Force equipments. However, there is little experience to date in the use of CERs to estimate total life cycle costs or operating and support costs. There is a great need for CERs that reflect operating and support costs as a function of design parameters that can be employed early in weapon system development. They are needed to enable decision makers to more explicitly consider the impact of alternative design concepts on operating and support costs. Estimating relationships that predict the costs of attaining various levels of equipment reliability are also needed in order to determine equipment reliability design goals that result in reduced life cycle costs.

Few CERs dealing explicitly with life cycle cost, operating and support cost, or reliability improvement cost exist at present. The models described below represent initial efforts to derive relationships of this type.

A. RELATIONSHIPS FOR ESTIMATING LIFE CYCLE COST OF AVIONICS SYSTEMS[9]

Objective of the Relationships: To reflect life cycle cost as a function of avionics subsystem design parameters in order to compare

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9. a. Coult, Jr. R., et al, "Aircraft Avionics Tradeoff Study, Volume II: Concept Development and Tradeoff, Part II, Equipment Tradeoffs," Honeywell, Inc., USAF Tech Report ASD/XR 73-18, Sep 1973.
b. Crowe, R. K., et al, "Aircraft Avionics Tradeoff Study, Volume III: Concept Application, Evaluation, and Implementation," Honeywell, Inc., USAF Tech Report ASD/XR 73-18, Sep 1973.

subsystem design alternatives in design areas such as subsystem packaging, commonality and over design on the basis of life cycle cost.

Description of the Relationships: A set of CERs was developed to examine the effects on avionics system life cycle cost of different design approaches to producing modularity, commonality and standardization. The CERs estimate the costs of RDT&E, procurement and operations and support. They incorporate production learning curves, Air Force provisioning policies, supply system management factors and repair, replacement and condemnation policies.

Unlike several existing models for estimating life cycle cost, these CERs compute LCC as a function of a relatively small number of parameters; namely, procurement cost, production learning curve factors, MTBF, number of subsystems, number of LRUs and flying hours per month per system. Hence, they can be used to compare the life cycle cost impact of differing design alternatives in equipment development when logistics parameters such as percent of failures repaired at depot (NRTS) and maintenance manhours per flying hour (MMH/FH) have not yet been estimated.

Prospects for Use of the Relationships: At present, the primary source of experience with these CERs is the Quick-Strike Reconnaissance Systems Analysis Study. This study was undertaken by the Design Analysis Branch of the Engineering Avionics Directorate at ASD.[10] Its purpose was to examine several alternative real time reconnaissance equipments in order to determine optimal mixes of equipment and optimal equipment deployment schemes. The CERs were used in this study to compare avionics equipments on the basis of life cycle cost.

B. RELATIONSHIPS FOR ESTIMATING OPERATING AND SUPPORT COSTS OF AVIONICS EQUIPMENT[11]

In this study, several cost estimating relationships (CERs) were developed for the purpose of forecasting yearly maintenance cost as a function of purchase price and certain design parameters such as mean time between failure (MTBF) and peak operating power. The study also developed factors for estimating initial spares cost, support equipment and support equipment spares cost as a percentage of equipment investment cost. Sources of data for the study included RADC, IDA, ARINC and AFLC. A primary problem encountered during this effort was considerable noise in the maintenance cost data. This caused several of the resulting CERs

10. The project manager for this study is Mr. Larry Beasley, ASD/ENA, Wright-Patterson AFB, Ohio 45433.

11. Cost Analysis of Avionics Equipment, Air Force Avionics Laboratory (AFAL) Technical Report 73-441, February 1974. This study was done for AFAL by General Research Corporation and was directed technically by Major Richard Grimm.

to have lower coefficients of determination than desired. Nevertheless, annual maintenance CERs for doppler and fire control radars and bomb-nav systems exhibited acceptable coefficients of determination and standard errors.

A follow-on contract is underway to develop a more comprehensive set of CERs in this area.[12] Particular attention will be given to more extensive use of MTBF and other design parameters as independent variables in these studies. Equipments to be considered include radar warning receivers, electronic countermeasures pods, inertial measurement units, radars, TVs, lasers and computers.

C. STATISTICAL RELATIONSHIPS FOR ESTIMATING COST OF RELIABILITY PROGRAMS[13]

Objective of the Relationships: (1) To provide a quantitative basis for estimating costs of reliability design programs, reliability parts programs and reliability testing programs so that these costs can be more explicitly considered and accurately estimated when budgeting for the development of avionics equipment. (2) To provide a method for giving visibility to the costs of achieving given levels of avionics equipment reliability.

Description of the Relationships: The following types of statistical relationships were derived.

1. Total reliability program cost (in man-days) as a function of resultant equipment MTBF and number of electrical parts in the equipment.

2. Cost of reliability design program, reliability parts program and reliability test program, each as a function of number of electrical parts.

3. Resultant equipment MTBF as a function of reliability parts program cost, reliability test program cost and number of electrical parts.

4. Incremental increase in reliability program cost as a function of incremental increase in MTBF.

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12. The project engineer for this contract is Capt Lee Darlington, AFAL/AAA-4, Wright-Patterson AFB, Ohio 45433.

13. Reliability Acquisition Cost Study, General Electric Company, (Salvatore P. Mercurio and Clyde W. Skaggs), Contract F30602-72-C-0226, Project 5519, Job Order No. 55190256, prepared for RADC (RBRS), Griffiss AFB, New York 13441 (Contract Monitor - Mr. Jerome Klion).

The relationships were developed using data from two manufacturers on ten equipments. Both aircraft and space equipments were considered. The reliability design program was assumed to include prediction, failure modes and effects analysis, and design reviews; the parts program was assumed to include parts screening specification, parts standardization and control, and vendor control; and the reliability test program was assumed to include evaluation testing, equipment environmental screening, and reliability demonstration testing.

These relationships can be used in trade-off and life cycle cost analyses to provide a heretofore missing link, namely, a relationship between reliability development cost and resulting reliability. They can also be used to determine the optimum size and mix of reliability program elements in any development environment that is similar to the one from which data for this study was gathered.

Prospects for Use of the Relationships: To date, there has been virtually no experience in using the CERs described above in design of new reliability programs because the relationships were developed so recently. However, there are plans to use them at two levels as described below:

1. The General Electric Company plans to use the CERs to structure reliability programs and estimate reliability program costs in future avionics development efforts.

2. In its capacity as monitor of several reliability programs at ASD and ESD, RADC plans to use the CERs to estimate the costs associated with these programs and to evaluate the levels of reliability improvement that are achievable with given levels of program funding.

In addition to these planned efforts, it is also hoped that analysts associated with SPOs will take the initiative to use the CERs in designing and budgeting for avionics reliability programs associated with their systems.

IV. RELIABILITY IMPROVEMENT COST MODELS

There is considerable evidence in the LCC literature indicating that more money spent to improve the reliability of present Air Force equipments could have resulted in far greater reductions in operating and support costs. The task of getting increased funding for reliability improvement work during the development cycle would be easier if development managers more clearly understood the relationship between equipment reliability and cost.

In recent years, several models have been developed for the purpose of explicitly identifying this relationship. Models of this kind can be very helpful in determining how much money should be budgeted to attain given levels of reliability and to determine the level of equipment reliability that minimizes life cycle costs.

The examples below represent two efforts to quantify the reliability-cost relationships.

A. A MODEL FOR EVALUATING WEAPON SYSTEM RELIABILITY, AVAILABILITY AND COSTS[14]

Objective of Model: To reflect the relationships among system and subsystem reliability and availability design requirements and life cycle costs in order to provide a basis for making cost effective trade-off analyses to determine the optimum reliability and availability requirements for a system and its component subsystems.

Model Description: The model is constructed to determine the optimum reliability for each of any number of subsystems which comprise a specific system, such that the total life cycle cost of the system, as affected by reliability, is a minimum. Three principle types of cost are considered in the model:

1. Cost of system downtime resulting from imperfect reliability. As reliability of a given subsystem decreases, downtime of the aircraft on which the subsystem is located tends to increase so that additional aircraft are needed to meet a given mission requirement. Downtime cost is defined in terms of the life cycle cost of these additional aircraft.

2. Design, development, acquisition and program management costs associated with achieving given levels of reliability. A

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14. "Criteria for Evaluating Weapon System Reliability, Availability, and Costs," Task 73-11, March 1974, Logistics Management Institute, 4701 Sangamore Road, Washington, D.C. 20016.

reliability growth model developed by J. T. Duane of the General Electric Company is used to reflect these costs.

3. Maintenance and support costs associated with system, subsystem, and component reliability. The approach used here is to identify, from total maintenance costs reported or estimated, that portion which is recoverable, i.e., the cost that would not be expended if a failure did not occur. This recoverable cost, therefore, comprises the component of maintenance and support cost that varies with subsystem reliability.

Examples of Model Use and Prospects for More Extensive Use: The model was used in conducting case studies of the F-4C, F-105D, B-52H, and C-141A aircraft systems. The purpose of the studies was to evaluate the life cycle cost savings achievable if, at the time of system development, the optimum subsystem reliability had been determined and achieved through a reliability growth program. Input data for the model was gleaned from AFLC systems G033B, D056, D165A, K051, Project ABLE and Project IROS. For each aircraft system, the model was exercised to determine the optimum MTBF for each major subsystem, the resultant MTBF for the entire system, and the total life cycle cost which would have been incurred if optimum MTBFs were achieved. The present MTBF experienced by each subsystem as found in the data was used to determine the life cycle cost under current MTBF conditions. The studies indicated in all four cases that there could have been significant reductions in life cycle cost if there had been additional investment in reliability growth during development. They also indicated that a 240 percent to 500 percent return on this additional investment could have been realized.

The model was also used in an analysis of the AN/APQ-120 radar on the F-4E. The analysis sought to determine whether this low reliability radar should be improved via installation of higher reliability parts or replaced by a high reliability radar, the WX-200. The study indicated that the former decision would result in a lower life cycle cost. This conclusion coincided with recommendations made by an Air Force/industry study that had been undertaken to determine a source of action with regard to this radar.

The examples above indicate that, under appropriate conditions, the model can be used to produce relatively good estimates of optimum reliability levels. Efforts should be undertaken to prove the usefulness of this modeling approach in more Air Force reliability programs.

B. A MODEL FOR TRADING OFF SYSTEM RELIABILITY PERFORMANCE AND COST[15]

Objective of Model: To find that set of subsystem ' 3F options that maximizes system reliability performance (in terms of mission completion success probability (MCSP)) subject to a constraint on total cost of the system, given several discrete options that vary in reliability performance (MTBF) and cost (acquisition cost or life cycle cost) for each of several subsystems of a weapon system.

Model Description: The model (known as the "Designing to System Performance/Cost" or "DSPC" model) was developed to be implemented with respect to a weapon system consisting of a set of mission critical subsystems. For each subsystem, estimates of parameters such as acquisition cost, MTBF and average cost per repair are required as input data. The cost by which system performance is constrained in the model may be acquisition cost or total life cycle cost.

The optimization procedure is simple and easily implemented. It yields a concave curve reflecting MSCP as a function of cost and consisting of straight line segments that connect vertex points. The curve has the following properties:

1. Each vertex represents the maximum MSCP achievable at the associated cost.

2. No combination of subsystem options will yield a point above the curve.

3. Moving along the curve from one vertex to an adjacent vertex is equivalent to changing only one subsystem option. Hence, intermediate points on this straight line segment can be realized (on a fleet basis) by equipping only a certain fraction of the fleet with the new option.

The model can be implemented with respect to existing systems when it is desired to determine an optimal allocation of funds for the reliability improvement of one or more of the system's subsystems.

Recent Experience with the Model: The model was recently used in support of a Target Activated Munitions Program at Eglin AFB and in support of the EF-111A Program Office at Wright-Patterson AFB.[16]

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15. Anderson, Richard H., et al, Models and Methodology for Life Cycle Cost and Test and Evaluation Analyses, OAS-TR-73-6, Section IV, Office of the Assistant for Study Support, DCS/Development Plans, Air Force Systems Command, Kirtland AFB, New Mexico 87117.

16. Further information on these efforts is available from Mr. Thomas E. Dixon, AFSC/XR/OAS, Kirtland AFB, New Mexico 87117.

V. LEVEL OF REPAIR ANALYSIS MODELS[17]

Another approach to reducing life cycle costs is the use of more effective and less costly maintenance or level of repair policies for Air Force weapons systems. Several mathematical models have been developed in recent years for the purpose of determining the least cost level of repair policy for new equipments as they are introduced into the Air Force inventory. Most of these models fall into one of the three categories described below:

A. SINGLE ITEM - SINGLE INDENTURE MODELS[18]

This type of model simply adds up the various costs of each of three maintenance alternatives for a given line replaceable unit (LRU): (a) discard at failure, (b) repair at base, (c) repair at depot; and identifies the least cost of the three policies. This type of model has some limitations:

1. It requires the use of an allocation procedure for costs of such items as support and test equipment that are used to repair more than one type of LRU. This usually results in a requirement for several iterations of the model for each LRU in order to ensure that LRUs designated for repair at a given location carry totally allocated costs.

2. It does not explicitly cost out which of the three alternatives should be used at lower levels of repair, i.e., the shop replaceable unit (SRU) level, the module level and the piece-part level. Instead, either an average or a maximum cost of the three alternatives at each of these lower levels is assumed to be known.

About 90 percent of all level of repair modules currently in the literature fall into this category. Some of the more notable among these are:

1. The Air Force Optimum Repair Level Analysis (ORLA) model as defined in AFLC/AFSC Manual 800-4. Various versions of this model have been used in several recent Air Force acquisition programs including the F-15 aircraft. In each of these cases, the model has been provided to the contractor as a minimum acceptable basis for

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17. Further information with respect to Level of Repair Analysis Models can be obtained from AFLC/AQMLE, Wright-Patterson AFB, Ohio 45433.

18. The term "indenture" refers to the level of hardware breakdown and disassembly, e.g., system, subsystem, line replaceable unit, shop replaceable unit, module and piece-part.

determination of a repair level policy, and the contractor has been encouraged to extend and/or improve the model to more accurately reflect peculiar properties of the particular equipment being considered.

2. The Navy Level of Repair Model as defined in Military Standard 1390.

3. The McDonnell Douglas Level of Repair Model.

B. SINGLE ITEM - MULTI INDENTURE MODELS

Like the single item - single indenture model, this type of model costs out the discard at failure, repair at base and repair at depot maintenance alternatives for a given line replaceable unit. But, unlike the single indenture type of model, it also explicitly costs out each of the three maintenance policies at the SRU, module and piece-part level.

This type of model shares the first limitation described above, i.e., it requires several iterations when costs of support and test equipment used on several LRUs are involved. It usually uses an optimization procedure such as dynamic programming to cost out each maintenance alternative. Three models belonging to this category are the General Dynamics SG-8 Model, the Hughes Cost of Ownership Model (HCOM) and the Naval Air Development Center Level of Repair Analysis Model for Engines. The Navy model determines the optimum set of repair levels using exhaustive enumeration.

C. SYSTEMS MODELS

The systems approach costs out maintenance alternatives at the subsystem level, i.e., one level of indenture higher than the first two approaches. Hence, it is more comprehensive than these approaches in that it more accurately considers the optimum sequence of maintenance actions necessary to correct a failure and return the subsystem to serviceable condition. In addition, it avoids the problem of allocating costs of support equipment used on different LRUs of a given subsystem.

The primary limitation of the systems approach is its extensive requirement for input data. It also has the cost allocation problem in cases where support or test equipment is used on more than one subsystem.

A prime example of the systems approach is the Air Force Range Model (RGM). This model uses dynamic programming to calculate the combination of repair procedures that will minimize support costs for the total subsystem. To date, it has not been implemented in total on a major acquisition program, largely because of its extensive input data requirements.

VI. MAINTENANCE MANPOWER PLANNING MODELS

Maintenance manpower requirements clearly have a significant impact on the costs of maintaining most Air Force equipments. Mathematical models can be used as an aid in making two types of maintenance manpower decisions: (1) in evaluating the effects of alternative equipment designs on maintenance manpower requirements and (2) in evaluating the impact on cost of alternative maintenance policies. Careful use of these models can bring about substantial reductions in life cycle cost.

The model described below utilizes simulation to estimate maintenance manpower requirements. Simulation is a numerical technique for conducting experiments on a digital computer with a mathematical model that describes the behavior of a system over extended periods of time.

A SIMULATION MODEL FOR ESTIMATING MAINTENANCE MANPOWER REQUIREMENTS[19]

Objective of Model: To provide an improved method for:

1. Estimating the maintenance manpower requirements of a weapon system under development.

2. Evaluating design tradeoffs for a weapon system under development on the basis of maintenance manpower requirements.

3. Comparing alternative weapon systems being considered for acquisition on the basis of maintenance manpower requirements.

4. Evaluating maintenance manning policies for weapon systems currently in the Air Force inventory.

Model Description:[20] The model simulates the function of flying a given set of aircraft, the function of maintaining this set of aircraft, and the interaction between these two functions. The functions are described to the model by parameters specified by the user. These inputs include:

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19. Further information about this model is available from Major D. C. Tetmeyer, ASD/ENC, Wright-Patterson AFB, Ohio 45433 or Mr. F. A. Maher, AFHRL/ASR, Wright-Patterson AFB, Ohio 45433.

20. This model is divided into a series of modules, the main one of which is the L-COM (Logistics Composite Model), developed by AFLC and the RAND Corporation (RM-5544-PR).

1. Data that describe the weapon system, e.g., unit cost, failure rates of subsystems and components, types of support equipment required by the system, etc.

2. Data that describe the maintenance plan, i.e., class of maintenance (e.g., unscheduled, scheduled or phase), type of maintenance (e.g., trouble-shoot) and resource requirements (e.g., maintenance crew size, task times and required manning specialties and skill levels.

3. Data that describe the mission, e.g., mission type, sortie length, priority, aircraft type, fleet size, lead times, delay times, launch times and spares availability.

The aircraft operations and support requirements and demands on aircraft imposed by the flight schedule interact with one another in the model. The model "flies" airplanes according to the mission schedule. As the schedule dictates, the model draws on the aircraft pool and processes appropriate numbers of aircraft (if available) through the presortie tasks (with the lead time for presortie processing determined by the user). Given that presortie tasks are completed in time to meet the mission schedule, the model "flies" the sortie. Concurrent with the accomplishment of the sortie, subsystem and component failure clocks are decremented (where these failure mechanisms are expressed in terms of "mean sortie between maintenance actions"). When the aircraft lands, it receives a basic postflight or turnaround postflight according to the operations schedule, and the model checks the clock values to determine if any failures have occurred. When unscheduled maintenance is performed, the model calls upon the various resource pools (manpower, spares and support equipment) to repair the malfunction. If resources prescribed for this task are depleted or devoted to another task, the aircraft must wait (where, depending on the priorities assigned by the user, one task may preempt another and the resources directed to the higher priority task). After the failed equipment is repaired, the aircraft is returned to the pool and becomes available for flying again if called for by the mission schedule. Failed components that are removed from the aircraft during unscheduled maintenance are channelled into the shop where they may be repaired or processed for NRTS (not reparable this station) shipment to the depot. Either of these actions will eventually result in the return of the component to the spares pool.

The output format of the model reflects the interaction among support resources and their relationship to operational capability. It has two parts: (1) a Performance Summary Report which provides detailed information on the level of operation achieved during the simulation, and on the use and expenditure of resources necessary to sustain that level and (2) a work center matrix which graphically depicts the number of personnel that must be available in a work center in order to meet

"on aircraft" demands for maintenance over the span of time represented in the model. The model can be run repeatedly, each time with differing mission requirements. The set of differing manning requirements that results from these runs can then be input as data points to a regression program which calculates equations that reflect optimal work center manning for all appropriate points in the operations spectrum. These equations, in turn, serve as inputs to a Manpower Program which generates a manpower document (Basic Authorization) for any given flying hour program.

Since the model is modular in structure, portions of it can be used for other purposes. For example, the impact of different design alternatives on manpower can be determined using the Performance Summary Report. This tool may be helpful in determining optimal mixes of manpower, spares and support equipment resources.

Recent Experience with the Model: This model has been successfully implemented in several Air Force programs so far, and prospects for future use are good. It has been used:

1. To estimate maintenance manning requirements during the prototype development phase of the A-X program.

2. To analyze the effects of design alternatives on maintenance manning in the A-10 program.

3. To compare the maintenance manning requirements of the A-10 and A-7 during the recent A-10 - A-7 flyoff.

4. To estimate maintenance manning requirements for the Air Combat Fighter source selection.

The model is currently being used by TAC to evaluate maintenance manning policies for several aircraft currently in the inventory. It is one of the central tools being used in the current effort to incorporate a life cycle cost estimating capability in DAIS (Digital Avionics Information System). Also, decisions have been made to use the model to compute maintenance manning requirements for the F-16, F-15, AMST and B-1 programs.

VII. INVENTORY MANAGEMENT MODELS

Better management of spares inventories can result in a significant reduction in the life cycle cost of a system. During the past several years, mathematical models that treat various aspects of managing inventory systems have been developed. One of these models, called METRIC (Multi-Echelon-Technique-for-Recoverable-Item-Control), was developed by the Air Force Logistics Command and the RAND Corporation. It is a method for determining optimal stock levels for recoverable items in a two-echelon, base and depot, inventory system. Recoverable items are expensive and represent about 65 percent of the Air Force's total investment in spares.

MOD-METRIC, an extension of METRIC, is an acronym for a mathematical model developed at Hq AFLC for the control of a multi-item, multi-echelon, multi-indenture inventory system for recoverable items, that is, items subject to repair when they fail. The objectives of the model are to describe the logistics relationship between an assembly and its sub-assemblies, and to compute spare stock levels for all echelons (e.g., base, intermediate and depot level shops) for the assembly and sub-assemblies with explicit consideration of this logistics relationship.[21] In particular, the model is used to determine spare stock levels at each echelon which minimize total expected base backorders for the assembly subject to a constraint on investment in spares. By changing the level of this constraint and solving the model repeatedly, a curve of minimum expected base backorders achievable versus dollars spent on spares can be derived for use in determining an appropriate level of investment for spares.

Required inputs to MOD-METRIC include frequency of removals of each subassembly, average resupply times, not reparable this station (NRTS) rates, average repair time at each echelon, etc. A well defined maintenance concept and repair level analysis are required by the model. However, the model can be used to determine the impact of alternative maintenance concepts on spares requirements once design options are defined.

MOD-METRIC has been implemented by the Air Force as a method for computing spare stock levels for the F-15. The B-1, A-10, F-16, AWACS and Space Shuttle Programs are also planning to use it. AFLC Pamphlet 57-13 provides detailed instruction on using the AFLC CREATE system to

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21. The logistics relationship is described in the model by an equation. This equation reflects the average resupply time of the assembly as a function of (1) the probabilities that a given assembly failure was isolated to each of the components comprising the assembly and (2) the average resupply time for each of these components.

access and use MOD-METRIC computer programs. These instructions may be used by personnel who perform analysis of resource allocation or are authorized to use MOD-METRIC to compute requirements.[22]

22. An article describing the MOD-METRIC technique, entitled "A Model for a Multi-Item, Multi-Echelon, Multi-Indenture Inventory System" by Major John A. Muckstadt, Hq AFLC, Wright-Patterson AFB, Ohio, can be found in Management Science, Volume 20, No. 4, December 1973, Part I.

VIII. WARRANTY MODELS

In recent months, the Air Force has been seriously examining the pros and cons of a more widespread use of reliability improvement warranties (RIWs) in the acquisition of new weapons systems and equipments. Recent studies have concluded that a properly constituted and applied warranty can yield significant reliability and LCC benefits. The Director, Procurement Policy, Hq USAF, has recently published a set of interim guidelines with respect to RIW application criteria, funding of RIWs, essential elements to be included in an RIW contract clause, determination of the cost-effectiveness of an RIW provision, and evaluation approaches for assessing the cost-effectiveness of an RIW after it has been implemented. It should be noted, however, that these guidelines provide no specific cost methodology to be used in determining cost-effectiveness. In order to bridge this gap, the Government must develop models that will compute parameters for aiding in making warranty-related decisions, e.g., optimal warranty time period and break-even costs. One such model is described on the following pages.

AN LCC MODEL FOR USE IN NEGOTIATING RELIABILITY IMPROVEMENT WARRANTIES[23]

Objective of Model: This model evaluates the life cycle costs associated with a reliability improvement warranty (RIW) provision in the procurement of defense avionic equipment. The model computes:

1. Savings achievable by using a warranty as a function of length of warranty period in order to determine an optimum warranty period length.

2. The break-even or "indifference" price for items purchased under a warranty provision as a function of length of warranty period, i.e., that price whereby the expected total user cost under warranty is equal to the total cost that the user would expect to incur without a warranty.

The model is developed to be applicable during the development and preproduction stages when consideration of a warranty provision for the production contract is most important.

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23. Use of Warranties for Defense Avionic Procurement, ARINC Research Corporation, sponsored by Defense Advanced Research Project Agency, ARPA Order No. 2360, also Final Technical Report No. RADC-TR-73-249, June 1973. The monitors for this contract were Mr. Russell Shorey, ODDR&E, The Pentagon, Washington, D.C. 20330 and Mr. A. Feduccia, RADC/RBRS, Griffiss AFB, New York 13440.

Model Description: The model considers three cost elements for any given equipment procurement: initial acquisition costs, direct costs associated with failures, and indirect costs associated with maintenance support. In simplified form, the model can be stated as follows:

> Life Cycle Cost over (0,T) = Number of units purchased x purchase price per unit + expected number of failures over (0,T) x cost per failure + maintenance support costs over (0,T).

The detailed form of the equation above depends on whether it is being formulated to reflect a warranty or a no-warranty situation. Except for direct reliability modification cost, the model assumes that the user incurs the same kinds of costs in the warranty case as in the no-warranty case. Clearly, his in-house direct maintenance costs will be less in the warranty case. His initial support costs will also be less, especially if his equipment is new to the inventory. However, there will be additional costs for warranty administration. The model assumes that all costs expected to be incurred by the contractor in the warranty case are included in the contract price, burdened by fee and risk factors.

Examples of Model Use and Prospects for More Extensive Use: To date, the RIW LCC model has not been used in a real world procurement because (1) it is very complex and, hence, difficult to understand, and (2) several of its assumptions regarding failure rates, effectiveness of modifications, etc., have not been sufficiently validated.

In late spring of 1974, a follow-on contract with the objective of making the model workable and useful as a decision tool was awarded.[24] Some of the contract's specific goals are:

1. To determine if the objectives of the model in the way it computes LCC in the no-warranty case are consistent with the objectives of the more traditional models that have been used to estimate LCC in recent procurements.

2. To more fully develop the concept of reliability growth during the warranty period in the model.

3. To implement the model on an experimental basis in some future procurements, e.g., the ARN-XXX TACAN currently in development.

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24. The monitor for this contract is Mr. Gene Fiorentino, RADC/RBRS, Griffiss AFB, New York 13440.

4. To determine the sensitivity of the model to labor rates and to examine the model's assumptions about labor rates.

5. To test the validity of the probability distribution used by the model to reflect the frequency of equipment modifications.

Appendix D

Bibliography

This bibliography lists the applicable regulations, pamphlets and other publications which can be used as a reference to key acquisition program activities related to life cycle cost analysis. The following categories have been selected:

- Requirements Definition
- System Acquisition Management
- Systems Engineering
- Reliability and Maintainability
- Procurement
- Test and Evaluation
- Costing/Financial Management
- Logistics
- Configuration Management
- Producibility
- Quality Assurance

Requirements Definition

AFR 27-9	Control and Documentation of Air Force Programs
AFR 57-1	Policies, Responsibilities, and Procedures for Obtaining New and Improved Operational Capabilities
AFR 57-4	Retrofit Configuration Changes
AFR 800-2	Program Management
AFSCR 27-1	Program Direction
AFSCR 800-18	Joint Operational and Technical Review (JOTR)
AFSCR/AFLCR 57-3	Class V Modification Management

System Acquisition Management

AFR 27-9	Control and Documentation of Air Force Programs
AFR 800-2	Program Management
AFR 800-4	Transfer of Program Management Responsibilities
AFSCR 27-1	Program Direction
AFSCR 27-6	The AFSC Programming Process
AFSCR 800-1	Command Review of Systems Acquisition Programs and Test Resources
AFSCP 800-3	A Guide for Program Management
AFSCR 800-10	Contract Management Support to Program Offices
AFSCR 800-18	Joint Operational and Technical Review (JOTR)
AFSCP/AFLCP 800-19	Joint Design-to-Cost Guide
AFSCP 800-23	Secretary of the Air Force Program Review/Program Assessment Review/Command Assessment Review (SPR/PAR/CAR) Guidance
AFLCM 800-1	Program Management
DODD 5000.1	Acquisition of Major Defense Systems (Attachment 3 to AFR 800-2)
DODI 5000.2	The Decision Coordinating Paper (DCP) and the Defense Systems Acquisition Review Council (DSARC) (Attachment 4 to AFR 800-2)
DODD 5000.26	Defense Systems Acquisition Review Council (DSARC) (Attachment 5 to AFR 800-2)
DODD 5000.28	Design to Cost
DODI 7000.3	Selected Acquisition Reports (SAR)
DODI 7045.7	The Planning, Programming and Budgeting System (Attachment 1 to AFR 27-90)

Systems Engineering

AFR 66-14	Equipment Maintenance Policies, Objectives, and Responsibilities
AFR 80-5	Reliability and Maintainability Programs for Systems, Subsystems, Equipment, and Munitions
AFR 80-13	Aircraft Structural Integrity Program (ASIP)
AFR 310-1	Management of Contractor Data
AFR 320-1	Air Force Value Engineering Program
AFR 400-44	Corrosion Prevention and Control Program
AFR 800-3	Engineering of Defense Systems
AFR 800-8	Integrated Logistics Support (ILS) Program for Systems and Equipment
AFR 800-11	Life Cycle Costing (LCC)
AFR 800-14	Management of Computer Resources in Systems
AFSCR 8-4	AFSC Design Handbooks
AFSCR/AFLCR 80-17	Air Force Engineering Responsibility for Systems and Equipment
AFSCR 310-1	Management of Contractor Data
AFSCR/AFLCR 310-2	Deferred Requisitioning of Engineering Data
AFSCM 310-2	Technical Publications Acquisition Management
AFSCP 800-3	A Guide for Program Management
AFSCP 800-6	Statement of Work Preparation Guide
AFSCP 800-21	A Guide for Program Managers: Implementing Integrated Logistics Support
AFSCR 800-25	Application of Military Specifications and Standards to DOD Procurements
DODD 4100.35	Integrated Logistics Support (ILS) Program for Systems and Equipment (AFR 800-8)
MIL STD 490	Specification Practices
MIL STD 499	System Engineering Management

Reliability and Maintainability

AFR 66-14	Equipment Maintenance Policies, Objectives, and Responsibilities
AFR 80-5	Reliability and Maintainability Programs for Systems, Subsystems, Equipment, and Munitions
AFR 80-14	Test and Evaluation
AFR 400-46	Increase Reliability of Operational Systems (IROS) Program
AFR 800-8	Integrated Logistics Support (ILS) Program for Systems and Equipment
AFR 800-11	Life Cycle Costing (LCC)
AFSCR 8-4	AFSC Design Handbooks
AFSCR/AFLCR 80-16	Qualification of USAF Equipment
AFSCP/AFLCP 400-11	Reliability and Maintainability Data Sources
AFLCP 800-3	Logistics Performance Factors in Integrated Logistics Support
AFLCM/AFSCM 800-4	Optimum Repair-Level Analysis (ORLA)
MIL STD 470	Maintainability Program Requirements (For Systems and Equipments)
MIL STD 471A	Maintainability Verification/Demonstration/Evaluation
MIL STD 721B	Definitions of Effectiveness Terms for Reliability, Maintainability, Human Factors and Safety
MIL STD 756A	Reliability Prediction
MIL STD 757	Reliability Evaluation From Demonstration Data
MIL STD 781B	Reliability Tests Exponential Distribution
MIL STD 785A	Reliability Program for System and Equipment Development and Production
MIL STD 1472A	Human Engineering Design Criteria for Military Systems, Equipment, and Facilities
MIL HDBK 217A	Reliability Stress and Failure Rate Data for Electronic Equipment
MIL HDBK 472	Maintainability Prediction

RADC Reliability Notebook

Procurement

AFP 70-1-5	DOD/NASA Incentive Contracting Guide
AFR 70-15	Source-Selection Policy
AFR 800-2	Program Management
AFR 800-11	Life Cycle Costing (LCC)
AFSCP 800-6	Statement of Work Preparation Guide
AFSCP/AFLCP 800-19	Joint Design-to-Cost Guide
ASPR	Armed Services Procurement Regulations
ASPM-1	Armed Services Procurement Regulations Manual for Contract Pricing
LCC-1	DOD Life Cycle Costing Procurement Guide (Interim)
LCC-2	DOD Casebook Life Cycle Costing in Equipment Procurement
LCC-3	DOD Life Cycle Costing Guide for System Acquisitions (Interim)
Interim Guidelines for RIW	

Test and Evaluation

AFR 80-14	Test and Evaluation
AFR 800-2	Program Management
AFSCR/AFLCR 80-16	Qualification of USAF Equipment
AFSCM 310-2	Technical Publications Acquisition Management
AFLCM 800-1	Program Management
AFSCP 800-3	A Guide for Program Management
DODD 5000.3	Test and Evaluation (AFR 80-14)

Costing/Financial Management

AFR 27-9	Control and Documentation of Air Force Programs
AFM 172-1	USAF Budget Manual
AFR 172-4	Uniform Procedure for Tracking Weapon Support System Program Estimates
AFR 173-1	Management of the Cost Analysis Program
AFR 173-8	Economic Escalation
AFR 173-10	USAF Cost and Planning Factors
AFR 173-11	Independent Cost Analysis Program
AFR 178-1	Economic Analysis and Program Evaluation for Resource Management
AFR 400-46	Increase Reliability of Operational Systems (IROS) Program
AFR 800-2	Program Management
AFR 800-6	Program Control - Financial
AFR 800-11	Life Cycle Costing (LCC)
AFR 800-17	Work Breakdown Structure (WBS) for Defense Materiel Items
AFSCR 27-6	The AFSC Programming Process
AFSCR 70-11	Surveillance of Management Control Systems and Financial Reporting on Selected Acquisitions
AFSCM 173-1	Cost Estimating
AFSCM 173-2	Cost Information System
AFSCP/AFLCP 173-5	Cost/Schedule Control Systems Criteria
AFSCP/AFLCP 173-6	C/SCSC Joint Surveillance Guide
AFSCP/AFLCP 400-11	Reliability and Maintainability Data Sources
AFSCM/AFLCM 800-4	Optimum Repair-Level Analysis (ORLA)
AFSCR 800-6	Program Control - Financial
AFSCP/AFLCP 800-15	Contractor Cost Data Reporting (CCDR) System

AFSCP/AFLCP 800-19	Joint Design-to-Cost Guide
AFLCM 66-18	Programming and Technical Processes
AFLCP 173-3	A Guide for Estimating Aircraft Logistics Support Costs
AFLCP 173-4	Estimating Depot Maintenance Cost for Air Force Aircraft
AFLCP 800-3	Logistics Performance Factors in Integrated Logistics Support
DODD 5000.4	OSD Cost Analysis Improvement Group
DODD 5000.28	Design to Cost
DODI 5010.20	Work Breakdown Structure for Defense Material Items
DODD 5010.29	Acquisition of Data from Contractors
DODI 7000.2	Performance Measurement for Selected Acquisition
DODI 7000.6	Acquisition Management Systems Control
DODI 7000.11	Contractor Cost Performance and Funds Status Report
DODI 7040.5	Definitions of Expenses and Investment Costs
DODI 7041.3	Economic Analysis and Program Evaluation for Resource Management (AFR 178-1)
DODI 7045.7	The Planning, Programming, and Budgeting System (Attachment 1 to AFR 27-9)
DOD 7110-1-M	DOD Budget Guidance Manual
MIL STD 881	Work Breakdown Structure for Defense Material Items
MIL STD 1388-1	Logistics Support Analysis
MIL STD 1388-2	Logistics Support Analysis Data Element Definitions
LCC-1	DOD Life Cycle Costing Procurement Guide (Interim)
LCC-2	DOD Casebook Life Cycle Costing in Equipment Procurement
LCC-3	DOD Life Cycle Costing Guide for System Acquisitions (Interim)

Interim Guidelines for RIW

Logistics

AFR 27-9	Control and Documentation of Air Force Programs
AFR 50-48	Management of Training Equipment
AFR 57-1	Policies, Responsibilities, and Procedures for Obtaining New and Improved Operational Capabilities
AFR 66-14	Equipment Maintenance Policies, Objectives, and Responsibilities
AFR 66-30	Product Improvement Program
AFR 66-38	Nondestructive Inspection Program
AFR 74-1	Air Force Quality Assurance Program
AFR 80-5	Reliability and Maintainability Programs for Systems, Subsystems, Equipment, and Munitions
AFR 80-13	Aircraft Structural Integrity Program (ASIP)
AFR 173-11	Independent Cost Analysis Program
AFR 178-1	Economic Analysis and Program Evaluation for Resource Management
AFR 400-44	Corrosion Prevention and Control Program
AFR 400-46	Increase Reliability of Operational Systems (IROS) Program
AFR 800-2	Program Management
AFR 800-4	Transfer of Program Management Responsibilities
AFP 800-7	Integrated Logistics Support Implementation Guide for DOD Systems and Equipment
AFR 800-8	Integrated Logistics Support (ILS) Program for Systems and Equipment
AFR 800-11	Life Cycle Costing (LCC)
AFR 800-14	Management of Computer Resources in Systems
AFSCM 65-2	Air Force Provisioning Policies and Procedures
AFSCR/AFLCR 80-16	Qualification of USAF Equipment
AFSCM 173-1	Cost Estimating
AFSCM 310-2	Technical Publications Acquisition Management
AFSCR 320-1	Air Force Value Engineering Program
AFSCR/AFLCR 400-10	Integrated Logistics Support of System Programs

AFSCP/AFLCP 400-11	Reliability and Maintainability Data Sources
AFSCR 800-1	Command Review of Systems Acquisition Programs and Test Resources
AFSCM 800-3	A Guide for Program Management
AFSCM/AFLCM 800-4	Optimum Repair-Level Analysis (ORLA)
AFSCR/AFLCR 800-5	AGE Acquisition Management
AFSCR 800-18	Joint Operational and Technical Review (JOTR)
AFSCP/AFLCP 800-19	Joint Design-to-Cost Guide
AFLCR 27-1	Class V Mod Prog Data (RCS: HAF-D17)
AFLCP 57-13	Recoverable Inventory Control Using MOD-METRIC
AFLCM 57-16	AGE Acquisition Control System
AFLCR 57-27	Determination of Requirements of Initially Provisioned Items
AFLCM 65-3	AF Provisioning Policies and Procedures
AFLCM 66-18	Programming and Technical Processes
AFLCR 66-28	Analytical Condition Inspection Program
AFLCP 173-3	A Guide for Estimating Aircraft Logistics Support Costs
AFLCP 173-4	Estimating Depot Maintenance Cost for Air Force Aircraft
AFLCR 523-1	Mission Assignment Policy
AFLCM 800-1	Program Management
AFLCP 800-3	Logistics Performance Factors in Integrated Logistics Support
MIL STD 1388-1	Logistics Support Analysis
MIL STD 1388-2	Logistics Support Analysis Data Element Definitions
LCC-1	DOD Life Cycle Costing Procurement Guide (Interim)
LCC-2	DOD Casebook Life Cycle Costing in Equipment Procurement
LCC-3	DOD Life Cycle Costing Guide for System Acquisitions (Interim)

Interim Guidelines for RIW

Configuration Management

AFR 57-1	Policies, Responsibilities, and Procedures for Obtaining New and Improved Operational Capabilities
AFR 57-4	Retrofit Configuration Changes
AFR 65-3	Configuration Management
AFR 310-1	Management of Contractor Data
AFR 310-3	Acquisition and Management of Data for Follow-On Procurements
AFR 320-1	Air Force Value Engineering Program
AFR 800-2	Program Management
AFR 800-4	Transfer of Program Management Responsibilities
AFSCR/AFLCR 57-3	Class V Modification Management
AFSCR/AFLCR 57-4	Management of Retrofit Changes During Acquisition
AFSCM 84-3	Production Management
AFSCR 310-1	Management of Contractor Data
AFSCM 310-2	Technical Publications Acquisition Management
AFSCM/AFLCM 375-7	Configuration Management for Systems, Equipment, Munitions, and Computer Programs
AFSCP 800-3	A Guide for Program Management
AFLCM 800-1	Program Management
MIL STD 480	Configuration Control - Engineering Changes, Deviations and Waivers
MIL STD 481	Configuration Control - Engineering Changes, Deviations and Waivers (Short Form)
MIL STD 482	Configuration Status Accounting Data Elements and Related Feature
MIL STD 483	Configuration Management Practices for Systems, Equipment, Munitions and Computer Programs
MIL STD 490	Specification Practices
MIL STD 499	System Engineering Management

Producibility

AFR 800-9	Production Management in the Acquisition Life Cycle
AFSCR 84-2	Production Readiness Review
AFSCM 84-3	Production Management

Quality Assurance

AFR 74-1	Air Force Quality Assurance Program
AFSCR 74-6	Procurement Quality Assurance for System Programs

Appendix E

Abbreviations and Acronyms

A	Availability
ABLE	Acquisition Based on Consideration of Logistics Effects
ACI	Analytical Condition Inspection
ACMS	Advanced Configuration Management System
ACO	Administrative Contracting Officer
ACWP	Actual Cost of Work Performed
ADL	Authorized Data List (TD-3)
AFPE	Air Force Preliminary Evaluation
AFPR	Air Force Plant Representative
AFPRO	Air Force Plant Representative Office
AGE	Aerospace Ground Equipment (see SE)
ALC	Air Logistics Center
ALE	Actuarial Life Expectance
AMPR	Aircraft Manufacturing Production Report
APP	Advanced Procurement Plan
ASIP	Aircraft Structural Integrity Program
ATE	Automatic Test Equipment
BA	Budget Authorization
BACE	The Planning, Programming and Budget Annual Cost Estimating (Model)
BCWP	Budgeted Cost for Work Performed
BCWS	Budgeted Cost for Work Scheduled
BITE	Built-In Test Equipment
BOS	Base Operations Support
BPAC	Budget Program Activity Code
BRC	Base Repair Cycle
CACE	Cost Analysis Cost Estimating (Model)
CAIG	Cost Analysis Improvement Group
CAO	Contract Administration Office
CAR	Command Assessment Review
CBS	Cost Breakdown Structure
CCB	Configuration Control Board
CCDR	Contractor Cost Data Reporting (AFR 800-6 and AFSCP 800-15)
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CER	Cost Estimating Relationship
CFE	Contractor Furnished Equipment
CFSR	Contract Funds Status Report (AFR 800-6)
CI	Configuration Item
CIP	Component Improvement Program

CIS	Cost Information System (AFSCM 173-2)
COD	Correction of Deficiency
CPA	Cost and Performance Analysis
CPR	Cost Performance Report (AFR 800-6)
CREATE	Computational Resources for Engineering and (Simulation) Training and Education
CRISP	Computer Resources Integrated Support Plan
C/SCSC	Cost/Schedule Control System Criteria (AFR 800-6 and AFSCP 173-5)
CWBS	Contract Work Breakdown Structure
DCAA	Defense Contracts Audit Agency
DCAS	Defense Contract Administration Services
DCP	Decision Coordinating Paper
D&F	Determination and Findings
DID	Data Item Description
DLM	Depot Level Maintenance
DPML	Deputy Program Manager for Logistics
DPPG	Defense Policy and Planning Guidance
DRC	Depot Repair Cycle
DSARC	Defense Systems Acquisition Review Council
DSD	Data System Designator
DTC	Design to Cost
DT&E	Development Test and Evaluation
EC	Event Counter
ECO	Engineering Change Order
ECP	Engineering Change Proposal
ENORS	Engine Not Operational Ready - Supply
ETI	Elapsed Time Indicator
FAD	Force Activity Designator
FAR	Field Assessment Review
FARADA	FAilure RAte DAta
FCA	Functional Configuration Audit
F&FP	Air Force Force and Financial Plan
FGC	Functional Group Code
FLU	First Line Unit
FMEA	Failure Modes and Effects Analysis
FOM	Figure of Merit
FOT&E	Follow-On Operational Test and Evaluation
FQR	Formal Qualification Review
FSD	Full Scale Development
FSED	Full Scale Engineering Development
FYDP	Five Year Defense Program
GFE	Government Furnished Equipment
GIDEP	Government/Industry Data Exchange Program
GSE	Ground Support Equipment (see SE)

HCOM	Hughes Cost of Ownership Model
IC	USAF Importance Category
I&C	Installation and Checkout
ICA	Independent Cost Analysis
ICE	Independent Cost Estimate
ICWG	Interface Control Working Group
ILS	Integrated Logistics Support
ILDF	Integrated Logistics Data File
ILSP	Integrated Logistics Support Plan
IM	Item Manager
IOC	Initial Operational Capability
IOD	Initial Operational Delivery
IOT&E	Initial Operational Test and Evaluation
IR&D	Independent Research and Development
IROS	Increased Reliability of Operational Systems
ISSL	Initial Spares Stock List
JFM	Joint Force Memorandum
JOCAS	Job Order Cost Accounting System (AFSCM 177-265)
JOTR	Joint Operational and Technical Review
JRDOD	Joint Research and Development Objective Document
JSOP	Joint Strategic Objective Plan
L	Logistics
LCC	Life Cycle Cost/Life Cycle Costing
L-COM	Logistics COmposite Model
LOR	Level of Repair
LPF	Logistics Performance Factors
LRU	Line Replaceable Unit
LSA	Logistics Support Analysis
LSAR	Logistics Support Analysis Record
LSC	Logistics Support Cost
LSPS	Logistics Support Plan Summary
M	Maintainability
MACE	Missile Annual Cost Estimating (Model)
MADARS	MAlfunction Detection, Analysis, and Recording System
MAMDT	Mean Active Maintenance DownTime
MAR	Management Assessment Report
	Minimum Acceptable Reliability
MCP	Military Construction Program
MCSP	Mission Completion Success Probability
MDC	Maintenance Data Collection
MDS	Mission Design Series (system)
MDT	Maintenance Down Time
MEA	Maintenance Engineering Analysis
METRIC	Multi-Echelon-Technique-for-Recoverable-Item-Control
MFP	Major Force Program
MFST	Missile Fleet Status Tool
MFTBMA	Mean Flying Time Between Maintenance Action
MH/FH or MMH/FH	Maintenance Manhours per Flying Hour
MH/T	Manhours per Task

MIL-HDBK	Military Handbook
MIL-STD	Military Standard
MIP	Material Improvement Project (Program)
MLE	Measured Logistics Effects
MLF	Maintenance Load Factor
MLSC	Measured Logistics Support Cost
MOD-METRIC	A Model for a Multi-Item, Multi-Echelon, Multi-Indenture Inventory System
MPA	Modification Proposal and Analysis
MSPG	Materiel Support Planning Guidance
MTBD	Mean Time Between Demand
MTBF	Mean Time Between Failure
MTBM	Mean Time Between Maintenance
MTBMT	Mean Time Between Maintenance Task
MTBO	Mean Time Between Other Than Failure-Related Maintenance Actions
MTBOF	Mean Time Between Operational Failure
MTBR	Mean Time Between Removal
MTT	Mean Task Time
MTTR	Mean Time to Repair
NORM	Not Operational Ready - Maintenance
NORS	Not Operational Ready - Supply
NRTS	Not Reparable This Station
NSN	National Stock Number
OFMDR	Organization Field Maintenance Demand Rate
O/H	Overhaul
OHRI	Overhaul Removal Interval
O&M	Operations and Maintenance
OPR	Office of Primary Responsibility
OR	Operational Ready
ORLA	Optimum Repair Level Analysis
O&S	Operating and Support
O&ST	Order and Shipping Time
PA	Program Authorization
P&A	Pay and Allowances
PACE	Planning Aircraft Cost Estimating (Model)
PAR	AFSC Planning Activity Report
	Program Assessment Review
PBD	Program/Budget Decision
PCA	Physical Configuration Audit
PCO	Procuring Contracting Officer
PCR	Program Change Request
PDM	Program Decision Memorandum
PDM	Programmed Depot Maintenance
PDR	Preliminary Design Review
PEM	Hq USAF Program Element Monitor
PHST	Packaging, Handling, Storage and Transportability (Program)

PI	Proposal Instructions
PIECOST	Probability of Incurring Estimated Cost
PM	Program Manager/Program Memorandum
PMD	Program Management Directive
PMP	Program Management Plan
PMR	Program Management Review
PMRT	Program Management Responsibility Transfer
PO	Program Office
POL	Petroleum, Oils, Lubricants
POM	Program Objectives Memorandum
PPBS	Planning, Programming and Budgeting System
PPGM	Planning and Programming Guidance Memorandum
PPE	Primary Program Element
PRR	Premature Removal Rate
	Production Readiness Review
PSE	Peculiar Support Equipment
QPA	Quantity per Application
R	Reliability
RAC	Reliability Analysis Center
R&D	Research and Development
RDT&E	Research, Development, Test and Evaluation
REDUCE	Research into the Economics of Design and User Cost Effects (Model)
RFI	Request for Information
RFP	Request for Proposal
RFQ	Request for Quotation
RGM	Range Model
RILSD	Resident Integrated Logistics Support Detachment
RIW	Reliability Improvement Warranty
R&M	Reliability and Maintainability
RO	Research Objective
ROC	Required Operational Capability
ROI	Return on Investment
RPG	Research Planning Guide
RPM	Real Property Maintenance
RTS	Reparable This Station
SAIP	Spares Acquisition Improvement Program
SAR	Selected Acquisition Report
SCIP	Systems Command Information Plan (AFR 800-6, AFSC Sup 1)
SE	Support and Test Equipment
SEDS	Systems Effectiveness Data System
SERD	Support Equipment Recommendations Data
SM	System Manager
SMR	Source, Maintenance and Recoverability (Code)
SOW	Statement of Work
SPD	System Program Director
SPO	System Program Office

SPR	Secretary of the Air Force Program Review
SRA	Specialized Repair Activity
SRU	Shop Replaceable Unit
SS	Source Selection
SSA	Source Selection Authority
SSAC	Source Selection Advisory Council
SSEB	Source Selection Evaluation Board
SYSTO	System Staff Officer
TA	Table of Allowances
TBO	Time Between Overhaul
TCTO	Time Compliance Technical Order
TD	Test Directive
TDR	Teardown Deficiency Report
T&E	Test and Evaluation
TEMP	Test and Evaluation Master Plan
TEOA	Test and Evaluation Objectives Annex (to PMD)
TLE	Target Logistics Effects
TLSC	Target Logistics Support Cost
TMS	Type, Model and Series (Equipment)
TN	Technology Need
TOA	Total Obligation Authority
TOD	Technology Objective Document
TPG	Technology Planning Guide
TPO	Technology Planning Objective
TRC	Technology Repair Center
TWG	Transfer Working Group
UE	Unit Equipment
UMR	Unsatisfactory Materiel Report
UNT	Undergraduate Navigator Training
UPT	Undergraduate Pilot Training
VE	Value Engineering
VECP	Value Engineering Change Proposal
WBS	Work Breakdown Structure
WRM	War Readiness Material
WUC	Work Unit Code

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This document is one of a series prepared to assist Air Force personnel understand and apply life cycle costing techniques. Other documents in this series include:

Life Cycle Cost Plan Preparation Guidance, October 1975.

Understanding and Evaluating Life Cycle Cost Models, October 1975

Supplemental Life Cycle Costing Program Management Guidance, January 1976

Analysis of Available Life Cycle Cost Models and Their Applications, June 1976

Life Cycle Cost Procurement Guide, July 1976

Copies of all of these documents are available from ASD/ACL, Wright-Patterson AFB, Ohio 45433.